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AUTHORITY

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25mm PLASTIC TELESCOPED CARTRIDGE CASE DEVELOPMENT PROGRAM

BRUNSWICK CORPORATION
TECHNICAL PRODUCTS DIVISION
ROUTE 1, BOX 300
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FINAL REPORT: MAY 1974 - SEPTEMBER 1974

AIR FORCE ARMAMENT LABORATORY
AIR FORCE SYSTEMS COMMAND • UNITED STATES AIR FORCE
EGLIN AIR FORCE BASE, FLORIDA

FOREWORD

This report documents the development of a plastic cartridge case during the period 1 May 1974 to 30 September 1974 by Brunswick Corporation, Sugar Grove, Virginia 24375, under Contract No. F08635-74-C-0089 with the Air Force Armament Laboratory, Eglin Air Force Base, Florida. The Program Manager for the Armament Laboratory was Major Stephen J. Bilsbury (DLDG).

The Brunswick Corporation Program Manager was Mr. D. E. Cary. Other Brunswick personnel that contributed to this program include Messrs. D. Blevins, B. Burkett and J. Y. Richardson.

This technical report has been reviewed and is approved for publication.

FOR THE COMMANDER

A. D. Brown Jr.

ALFRED D. BROWN, JR., Colonel, USAF
Chief, Guns, Rockets & Explosives Division

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INTRODUCTION

This was a joint exploratory development program by the U.S. Air Force Armament Laboratory and the U.S. Army Armament Command to provide a 25mm automatic cannon for tri-service application. The program was based on the utilization of GAU-7/A telescoped ammunition and gun technology to develop a 25mm cased telescoped cartridge and a high performance rapid fire cannon without the tri-service operational limitations associated with the GAU-7/A caseless system. The primary responsibilities of the U.S. Air Force were the design, fabrication, test and evaluation of the 25mm cartridge. The cartridge included the plastic cartridge case, the projectile and the propulsion charge. The U.S. Army was primarily responsible for the design, fabrication, test and evaluation of critical components and subsystems and for establishing a design base for the development of a high performance cannon and associated ammunition feed and storage systems.

The objective of this program was to develop a lightweight, low cost, all plastic cartridge case which would represent a major advancement in ammunition technology. The use of cartridge cases which were designed and produced to exploit the many desirable properties of non-metallic materials would provide the Air Force with many benefits such as: (i) reduced weight, (ii) conservation of critical materials, (iii) reduced thermal and mechanical damage to guns and (iv) consequentially reduced cost of gun systems operations.

This development effort covers the design, fabrication, test and delivery to Eglin Air Force Base of 2500 non-metallic cased 25mm cartridges.

This program required the integration of several advanced state-of-the-art concepts such as molded propellant charges, fully telescoped cartridge configurations, and plastic banded projectiles into an optimized plastic case to achieve maximum density and thus a minimum ammunition envelope. This section discusses the major technical consideration in the design and development of the cartridge case.

The two major tasks in the program were the design and development of the plastic cartridge case and the achievement of the desired ballistic performance for the complete cartridge. In order to succeed in these efforts, several design considerations were evaluated. Although satisfactory cartridge performance was desired in a compatible single shot fixture, it was assumed that, ultimately, the cartridge must be compatible with a high rate-of-fire automatic gun. Therefore, a great deal of consideration was given to the evaluation of design factors (Table 1) that represent this more severe environment.

TABLE 1 - DESIGN FACTOR CONSIDERATIONS

Cartridge Head
Chamber Clearance
Seal Interface
Cartridge Case
  Wall Thickness
  Length
  Contour (Degree of base taper)
  Extraction
  Material

The brass cartridge case evolved as a practical solution to problems encountered with repeating, breech-loading firearms. The typical cartridge case must perform the following functions:

(a) Contain the propellant and ignitor in a package for handling and environmental protection.

(b) Hold the projectile in proper relationship to the propellant and ignitor.

(c) Contain a means for propellant ignition (primer).

(d) Provide a breech seal.

(e) Provide a chamber seal.

(f) Provide an easy means of extracting spent cases and misfires.

If any of these functions cannot be or are not performed by the cartridge case, then they must be accomplished elsewhere in the gun system. For example, caseless and consumable cased cartridges depend upon the gun mechanism for breech and chamber sealing. Overall cartridge case requirements must be coordinated with the gun design for final definition.

The plastic required for a cartridge case must be a tough, relatively high modulus material, with a high glass transition temperature, a reasonably large value of elongation at failure, a dense molecular packing, and a chemically resistant polymer. The glass transition temperature identifies a physical property in amorphous and crystalline polymers where the material undergoes a sharp change in mechanical properties. Below this temperature the material is hard and brittle, but above it the material begins to soften and does not exhibit tensile strength.

It was felt that the structural problems associated with plastic cartridge cases would have development priority and other considerations such as moisture vapor transmission, long term propellant compatibility, effects of solvents, aging, et cetera, would not be evaluated at this time. It is apparent that the solution of many of these long term problems may not be fully achievable with one material. It may be necessary to protect the plastic structural substratum with other materials more resistant to the effects of the environment.

The GAU-7/A program objectives, ballistic performances obtained, the significant factors that induced unacceptable performance and the identified problem areas were reviewed. The objectives were to demonstrate the feasibility of a high rate of fire gun, using a 25mm telescoped caseless cartridge, over a temperature range of -65°F to +160°F, to protect caseless ammunition from the effects of humidity and to provide obturation in the gun. It was felt that the problem areas were due to changes in environmental conditions and seal leakage in the gun. Associated changes in internal free volume of the chamber resulting from thermal expansion were calculated based on the GAU-7/A operational environments and determined not to be of significant effect on the interior ballistic performance of the cartridge. The humidity and gun associated factors were minimized through the utilization of the plastic case and a new gun design that minimized leakage. Changes in environmental temperature had the most significant effect on ammunition performance because of the influence on the reaction rate processes that control the shot start sequences of the telescoped projectile.

The single shot test fixture designed by the U.S. Army Armament Command incorporated a unique breech concept developed by GATX under a 20mm plastic cased ammunition development contract to the U.S. Air Force.

The results of the program demonstrated the feasibility of the plastic cartridge case in a single shot fixture at ambient temperature and -65°F. However, satisfactory ballistic performance was only obtained at ambient conditions.

SECTION II

DESIGN DESCRIPTIONS

2.0 General.

The 25mm plastic cased telescoped round of ammunition, the cartridge case, the forward chamber seal, the plastic primer, the single shot test fixtures and the ballistic performance goals are described in this section.

2.1 Telescoped Plastic Cased Ammunition.

The round configuration selected as a baseline was a GAU-7/A cartridge because of the technological base established and demonstrated in the GAU-7/A Program. The GAU-7/A cartridge was composed of a forward and an aft charge of molded propellant, a nitrocellulose-mylar® projectile retainer, a nitrocellulose outer shell, a combustible primer and a 3000-grain, plastic banded projectile. The GAU-7/A cartridge is shown in Figure 1. The plastic cased cartridge replaced the combustible outer shell with a plastic material and the combustible primer with a conventional metal primer as shown in Figure 2.

The dimensions of the GAU-7/A cartridge and the gun chamber were made based on the conditions of a hot, moist cartridge and a chamber at -65°F. It was necessary that the cartridge chamber without damage. The maximum outside diameter of the combustible case was limited to 1.595 inches. A similar analysis with the plastic case indicated that the maximum diameter could be increased by 0.020 inch and remain compatible with the GAU-7/A chamber. This increase in diameter allowed a corresponding 0.020 inch increase in the molded propellant charge diameters. The projectile tip was positioned 0.1 inch from the forward end of the cartridge. This provided an aft charge length 0.2 inch greater than the GAU-7/A aft charge. The increased dimensions of the charges resulted in a propellant charge weight potential of 143 grams. This propellant weight resulted in a propellant charge-to-projectile mass ratio similar to the GAU-7/A ammunition. The projectile was retained inside the cartridge with a composite washer made from mylar® and nitrocellulose paper or felt. The primer and booster composition were contained in a caliber .32 pistol cartridge case that was inserted in the head of the plastic cartridge case. Gun breech obturation was provided by both the case and a plastic seal in the forward end of the cartridge. The cartridge was crushed 0.050 inch in length during chambering to minimize the annular spaces that exist at the chamber wall and to reduce stress levels in the case that will occur from axial tension caused by bolt deflection. The cartridge components are shown in Appendix A.

2.2 Plastic Cartridge Case.

The unusual designs of the ammunition and of the chambering and extraction features of the Rock Island Arsenal gun permitted a cartridge case design (Figure 3) with a uniform wall thickness. As shown in Figure 4 the molded propellant provided internal structural support and the telescoped

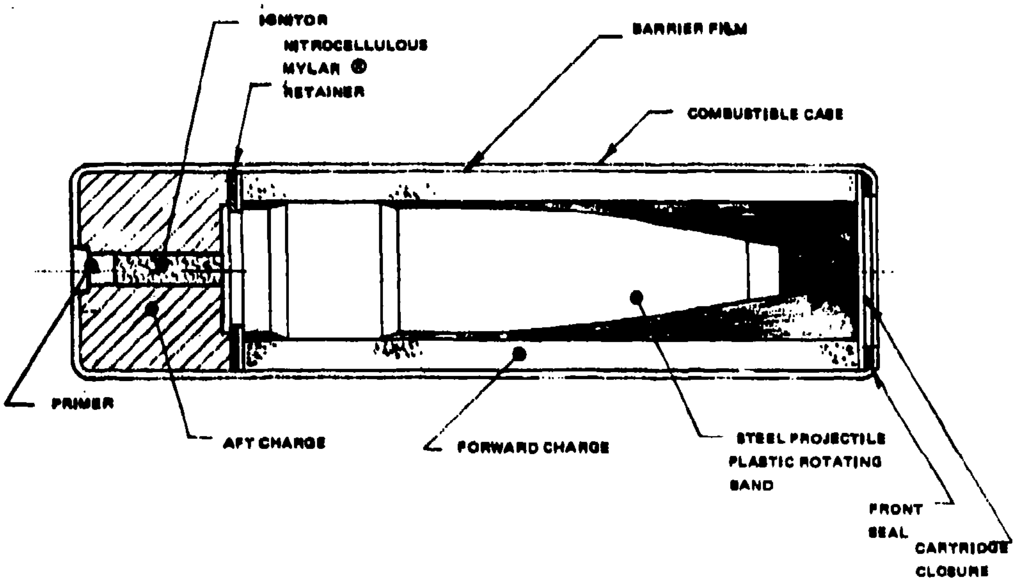


Figure 1. 25mm Caseless GAU-7/A Cartridge

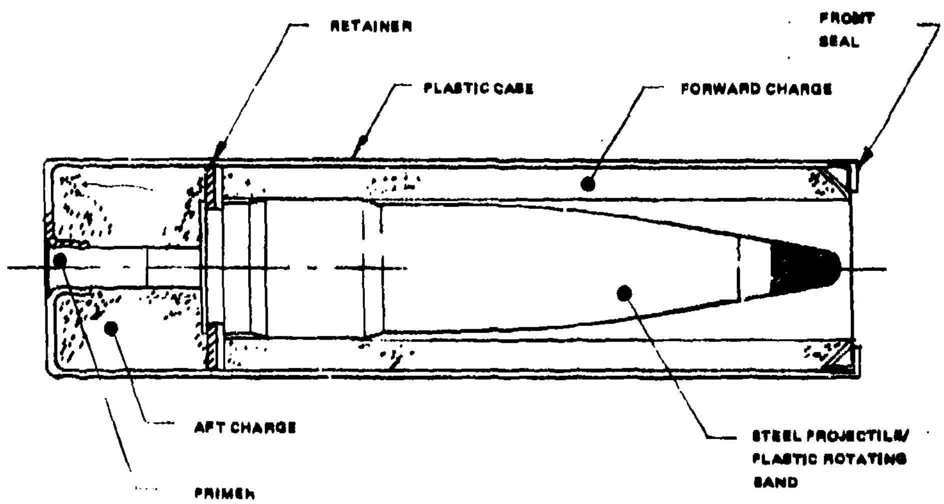


Figure 2. 25mm Plastic Case Cartridge

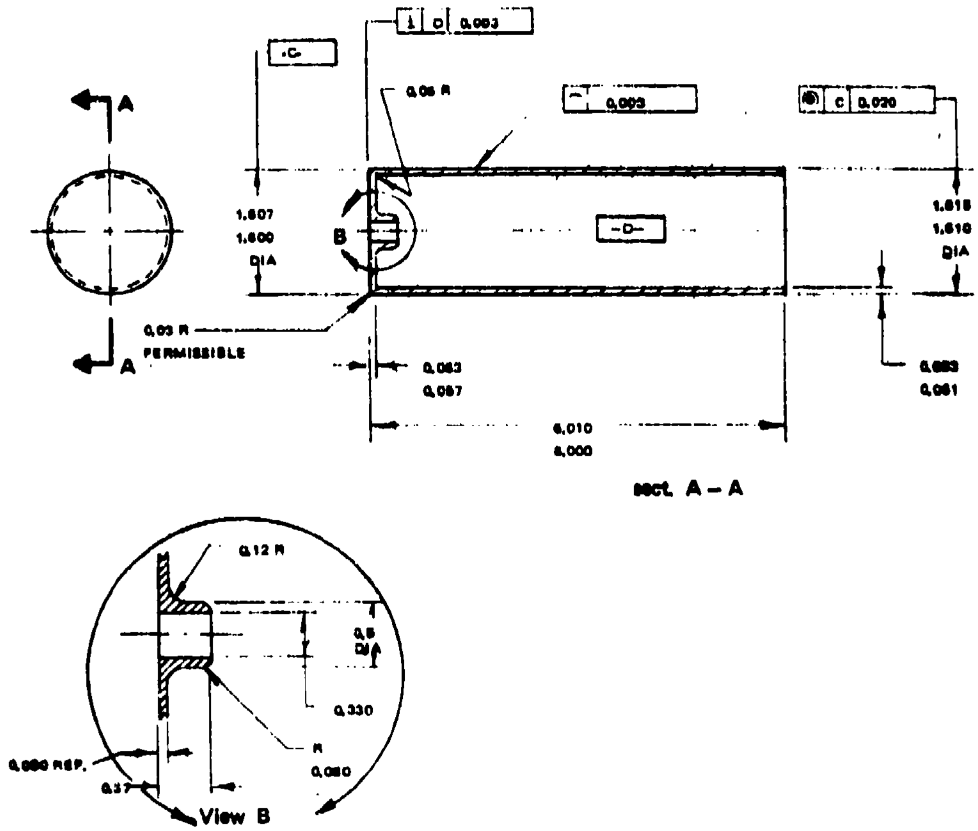


Figure 3. 25mm Plastic Case

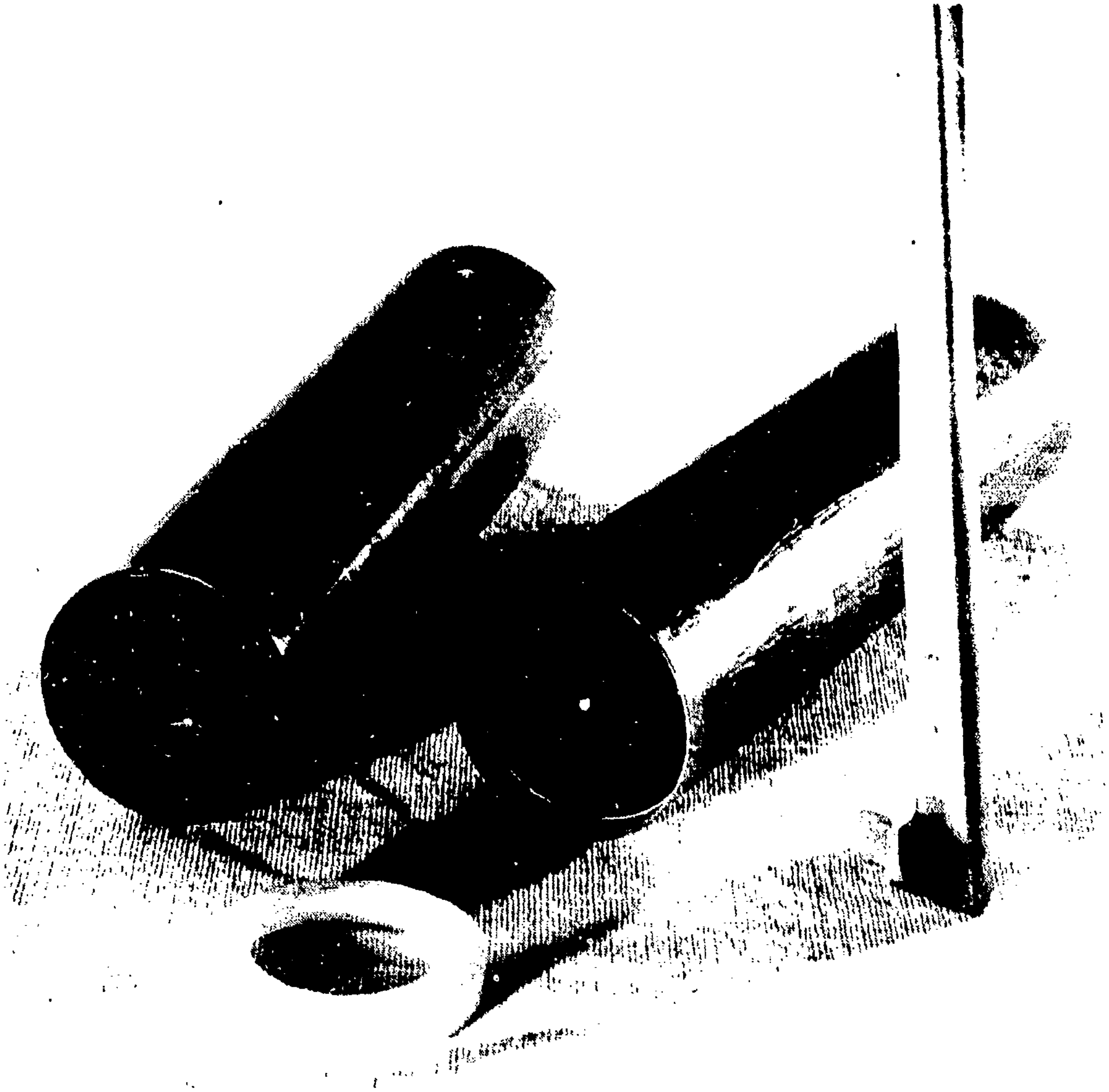


Figure 4. Cartridge Showing Telescoped Projectile, Molded Charge, Plastic Seal and Case Wall Profile

projectile eliminated the cantilever loads normally encountered with conventional cartridges.

The most severe structural environment for the cartridge case exists in the gun when the round fires. The body of the case must rapidly expand to the chamber wall and provide a high pressure gas seal against the chamber. With conventional ammunition, this expansion must take place before the projectile has left the case mouth or leakage will occur. Substantial shot start resistance must, therefore, be maintained between the projectile and case mouth, or the pressure in the cartridge may release the projectile before sealing occurs at the chamber wall. Premature gas leakage will erode the chamber, bolt face and possibly damage the receiver.

The expansion of the cartridge case must take place quickly (usually less than one millisecond) under a rapidly rising impulsive load (30,000,000 psi per second is a typical value for brass cased ammunition). Irregularities, density variations, strength variations, or section changes concentrate the strain in the affected areas and may cause failure of the case wall or the head at the primer aperture. Whether or not a metal insert to hold the primer is necessary depends on the firing pin interface, the cartridge headspace, and the type of plastic in the case. Primer retention failures in plastic cases result from the low tensile strength and modulus of the plastic, and from the low coefficient of friction between plastic and the metal primer which provides an inadequate friction load to hold the primer in place. If the headspace is too large, the primer may blow out directly or the case head may crack starting at the primer hole. These failures may be overcome either by providing a metal insert for the primer area to accommodate primer staking and seating, or very close firing pin support and minimum head space to minimize case head flexure and reduce primer/case relative motion.

Both filled and unfilled thermoplastics were candidate case materials. The glass filled materials have adequate mechanical properties other than being generally limited in elongation to approximately five percent at failure. Unfilled plastics have adequate elongation but inadequate tensile strength. These properties directly affect the cartridge/chamber interface.

The chamber clearance problem is aggravated in automatic guns as a result of thermal expansion of the chamber and the necessary tolerances to permit free working of the mechanism. The amount of clearance between case and chamber is a much more critical factor with a plastic case than with a metal case. This clearance largely determines whether or not failures will occur in the case during firing. After firing, the case must be able to quickly relax from the chamber wall to permit extraction. Too much clearance permits too much yield in the case and causes interference with the chamber when the pressure decays. Three suppositions intensify this condition when plastic cases are used. These are:

(a) Generally unfilled plastics display a large hysteresis when unloaded rapidly. The material returns to an intermediate state of deformation, relaxes and slowly creeps back to an unloaded configuration. The rate of return and the final configuration depends upon the percent elongation and the elastic limit of the material.

(b) Lower value of restoration force requires that the chamber pressure must "blow down" to a lower value before the case can begin to relax. This increases its relaxation time.

(c) Hot gun chamber surfaces that result from heat conduction through the receiver from hot gun barrels will soften the outer surface of a plastic cartridge case, causing partial adhesion of the case to the chamber if a cartridge case were left in the chamber after a long firing burst.

Such considerations strongly favor the glass or graphite filled thermoplastics or the thermosets with their higher modulus, higher heat distortion temperature, and lower thermal conductivity.

The material selected as the baseline for performance comparison was Hüls Nylon 12 with 33 percent glass fiber reinforcement. Each of the cartridges were injection molded by Irvine Plastic Inc., Downey, California. A subcontract was awarded to DeBell and Richardson, Inc., Enfield, Connecticut for designing and fabricating an injection mold for molding a wide variety of plastic materials. The tooling was completed but contract termination prevented its utilization. The materials planned for evaluation included the following:

38% glass filled nylon 12 (Hüls 1938)

50% glass reinforced nylon 12 (Thermofil® N9-5000 FG)

40% glass reinforced nylon 12 (Thermofil® N9-4000 FG)

49% glass reinforced nylon 6/12 (Thermofil® N6-4900 FG)

43% glass reinforced nylon 6/12 (DuPont 77G43)

30% glass filled nylon 11 (Rilsan® ZM 30)

40 Shore D Hytrel® (DuPont 4055)

55 Shore D Hytrel® (DuPont 5525)

63 Shore D Hytrel® (DuPont 6345)

Natural nylons 11, 12 and 6/12.

Note: For suppliers see Appendix B.

A thermoset epoxy/glass fiber composite case shown in Figure 5 was also evaluated. The cases were fabricated by filament winding technology developed at Brunswick's Lincoln, Nebraska plant. Tubes of the correct diameter were fabricated three feet in length. Cases were machined from each of the tubes. Steel heads and seals were bonded with Reichold's Epotuf® 37-139 adhesive to each end of the case providing an assembly.

Both the injection molded thermoplastic and the epoxy/glass thermoset cases were a minimum, reverse taper design to be compatible with a gun extraction mechanism that functioned on either a push-out or push-through principal. The push-out function ejects the cartridge from the same end of the chamber as it was loaded and allows minimum wall taper to assist in disengagement from the chamber wall and provide cartridge orientation for component assembly. The push-through principal ejects the cartridge from the opposite end of the chamber similar to that used in the GAU-7/A system and requires a minimum or no taper in the case wall.

The tapered wall case for the push-out extraction principal has the potential of fewer extraction difficulties. Provided the case wall is sufficiently stiff, a portion of the extraction stroke could be used to free a bound case from the chamber wall permitting relatively low extraction forces. The straight or minimum taper case, on the other hand, would if bound, require high extraction forces throughout the complete extraction cycle. These forces would result in buckling of the case wall or failure of the case head. The filament wound configuration has no taper and will be compatible only with the push-through principle.

In either system, the telescoped molded propellant configuration offers a significant reduction in the loads the case must bear during misfire extraction compared to conventional ammunition. Although the loads imposed are high due to the additional weight of projectile and propellant, the compressive strength of the molded propellant will reinforce the case, eliminating all but local deformation.

2.2.1 Cartridge Head. The cartridge head was designed to support the firing pressure across the breech-to-chamber interface and to maintain the primer/ignitor integrity. The head exterior was a right circular cylinder geometry with a flat bottom and a relatively sharp outer corner and a 0.060 radius on the inside at the junction of the head base and case sidewall. The exterior was shaped to facilitate gun breech support. Discontinuities, irregularities and changes in case head to wall thickness were minimized to reduce localized strain and stress risers because the case wall must move out to the chamber at firing. The wall is considerably less stiff in hoop than is the head.

The effect of the gun interface is of critical importance in designing the head. The gun chamber and breech must provide as much support as possible for the cartridge in this area. The location and width of the gun breech to chamber parting line must be selected commensurate with other gun requirements to provide the minimum width gap for the case to span. This parting line should be located and sized such that the minimum gap can be

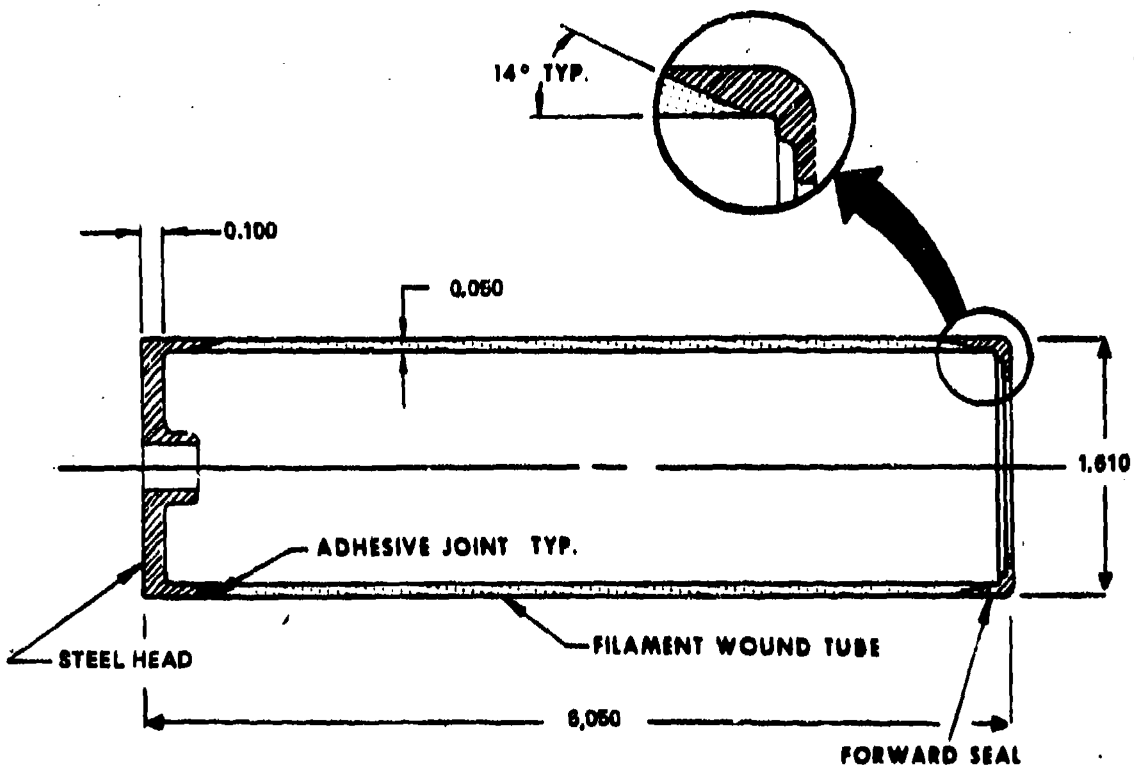


Figure 5. Glass Filament Wound Case

maintained under thermal growth of the gun and during receiver expansion and elongation in firing. To the greatest extent possible, the gun breech should provide line-of-contact support for the case head and the gun breech firing pin gap should be inside the primer diameter. The Brunswick Universal Gun and the Rock Island Arsenal Mann Barrel were designed with these considerations in mind.

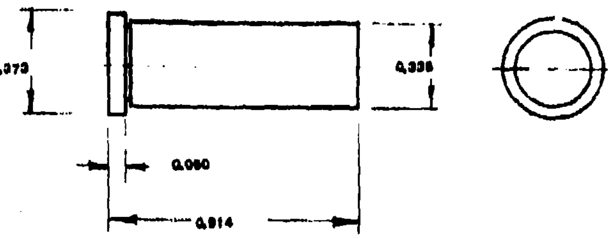
The filament wound cartridge case was tested initially with a metal head, to be replaced with a molded glass reinforced thermoset head or an injection molded thermoplastic head if initial tests warranted further investigation. In this assembly the body-to-head joint problem is partially overcome by locating the joint in the case wall at an area of constant cross section.

2.2.2 Ignitor Cartridge. The baseline cartridge concept utilized a caliber .32 Smith & Wesson (S&W) long, rimmed, straight case to house the ignitor and primer (Figure 6). This was necessary primarily to overcome any primer retention problems in the initial stages while other areas of the case and the cartridge ballistics were being evaluated. The primed caliber .32 S&W cartridge case was housed by a relatively thin walled shoulder in the plastic case head. The metal case was a light press fit into this shoulder and seated flush with the head. The metal case was retained and sealed at firing by gas pressure expanding the S&W cartridge against the plastic shoulder. After the general behavior of the plastic cartridge case in firing was ascertained, it was planned that the S&W cartridge would be replaced with a molded plastic primer.

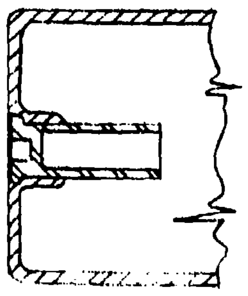
2.2.3 Case Wall. The case wall must be of relatively constant cross section to eliminate areas of high strain. Tapers were designed to be small and gentle. Irregularities or discontinuities were avoided if at all possible. A great deal of consideration was given to the phenomenon of dynamic straining in designing the case wall. Theoretically, the case wall should have a constant hoop and longitudinal stiffness throughout. Any sudden change in the level of stiffness will concentrate the strain in the weak area. Strains at firing may approach 100 percent at these discontinuities, resulting in failure. Discontinuities in injection molded parts include poor weld lines, flow orientation and areas of reinforcing fiber concentration. Assembly discontinuities include spin and ultrasonic weld lines, bond joints, and attachment points.

With telescoped ammunition, where the propellant is located forward of the projectile, the projectile begins moving before any significant gas pressure is applied at the case mouth. The pressure is in the rear portion of the case near the head. Sealing is, therefore, facilitated if the case wall in this area is a minimum thickness. Therefore, a small or zero taper in wall thickness is preferred. For these reasons the initial Brunswick case concept utilized a nearly constant wall thickness.

2.2.4 Case Mouth/Forward Seal. The design of a successful forward seal was anticipated to be critical in the development of a fully telescoped plastic cased cartridge. The seal configurations evaluated are illustrated



.32 CALIBER SMITH & WESSON LONG CARTRIDGE



CASE HEAD CROSS SECTION

Figure 6. Case Head Cross Section and Smith & Wesson Cartridge

in Figure 7 and the gun chamber interface is shown in Figure 8. Detailed drawings are shown in Appendix A.

The forward seal must provide an initial low pressure seal against the barrel face at shot start and a high pressure seal against the barrel face and across the chamber/receiver parting line at peak chamber pressure. The initial barrel face seal is necessary to prevent gas leakage at low pressure since the use of pressure drop to achieve the high pressure seal is precluded.

There are two possible ways of achieving an initial barrel face seal. The first method is to mechanically bring the cartridge and the seal into contact with the barrel face (crush-up). The second method is to utilize the shot start cycle of the telescoped round to affect the seal. It is known that the front propellant charge will move forward and bear with considerable force against the forward end of the cartridge when the ignitor fires. This is due to load transmission through the projectile retention system and the build-up of pressure in the rear propellant charge. Once a barrel face seal is achieved, the build-up of chamber pressure can be utilized to hold the forward seal against the barrel face.

There must be some relative longitudinal motion between the sealing face of the forward seal and the cartridge case; the sealing face must remain stationary against the barrel face while the case moves with the elongation of the receiver. At the same time there must be no relative radial movement between the seal and the case or gas leakage will occur between the case and the radial sealing face. In addition, the longitudinal movement of the seal must be restricted or it will become detached from the case and fall out during extraction.

The forward seal may be placed outside (Figure 9) or inside (Figure 10) the case mouth but must be mechanically attached in the longitudinal direction to the case wall. To effect a radial seal, the junction between the seal and the case wall must be maintained under the forces exerted by the rising chamber pressure. The configuration with the seal attached to the outside of the case requires that the case, when pressurized, carry the seal to the chamber wall. The concept with the seal on the inside of the cases requires that the seal carry the case to the chamber wall. This mechanical movement requires that the seal material possess mechanical properties that are similar to the case material. A stiff metal seal, for example, would cause case failure at the seal junction. Metal seals were not anticipated to be satisfactory but were evaluated for baseline comparative purposes.

An alternate concept of seal positioning was evaluated. The mechanism was based on the early portion of the shot start cycle utilizing the forward motion of the projectile to force the seal into position. The inside diameter of the seal was smaller than the outside diameter of the projectile to ensure that an interference condition would exist when the projectile enters the barrel. The concept is illustrated in Figure 11.

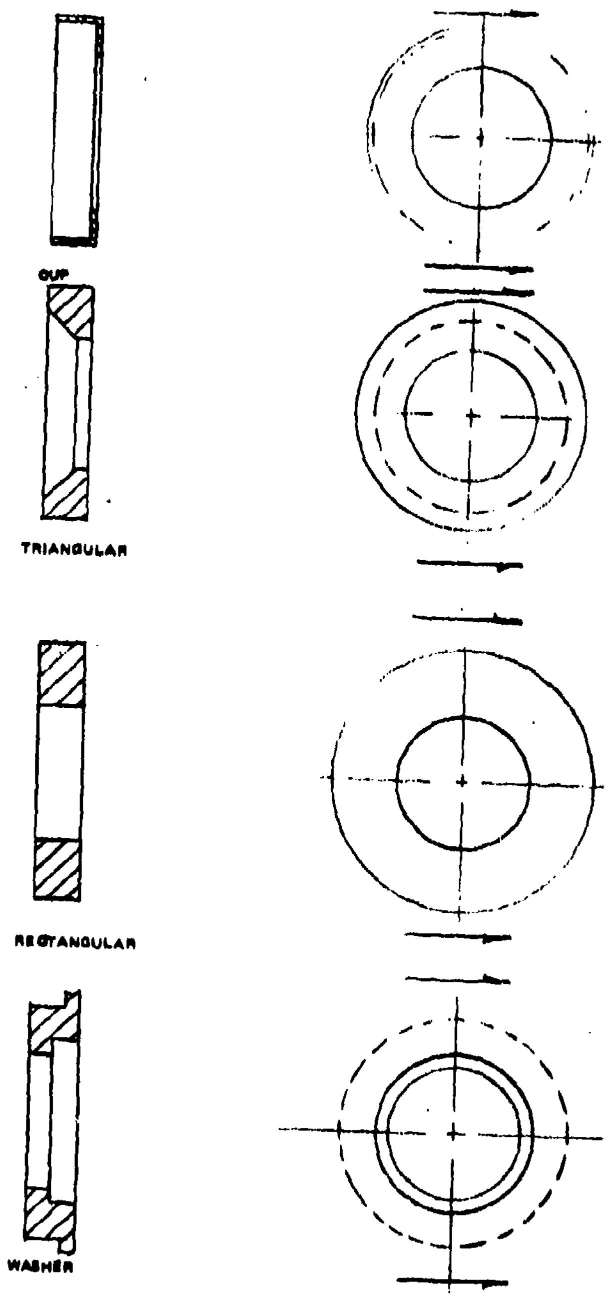


Figure 7. Chamber Seal Geometries

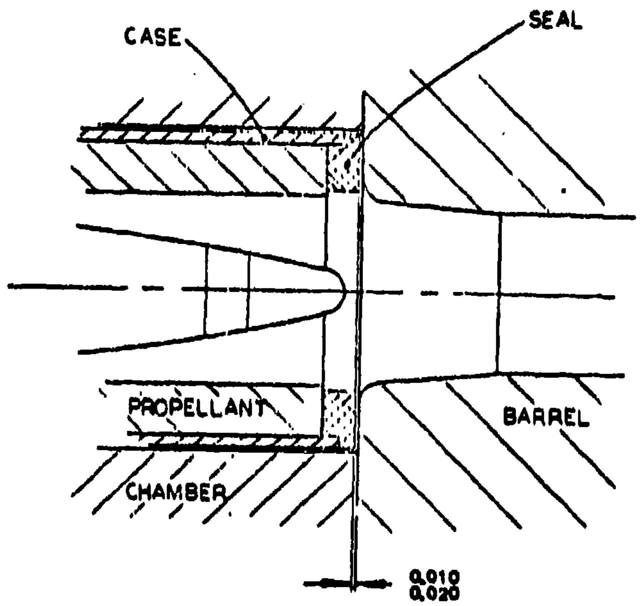


Figure 8. Seal Interface

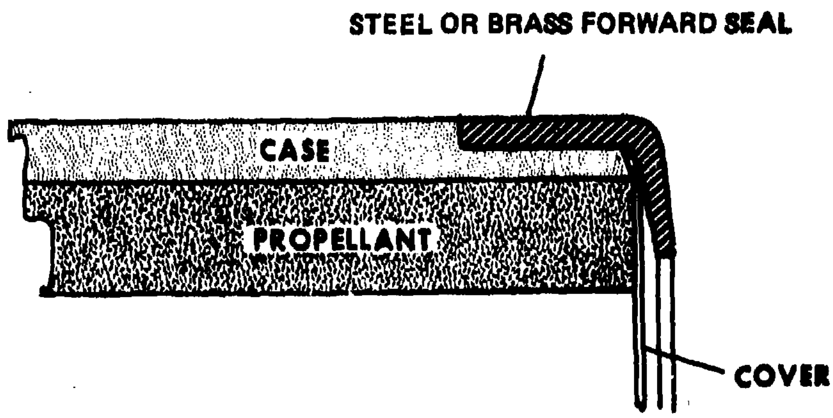


Figure 9. Metal Chamber Seal Assembly

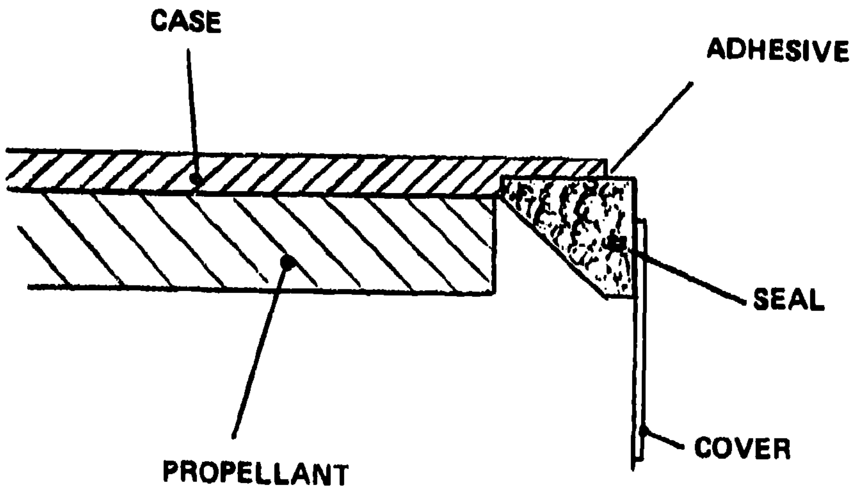


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Figure 10. Non-Metallic Chamber Seal Assembly

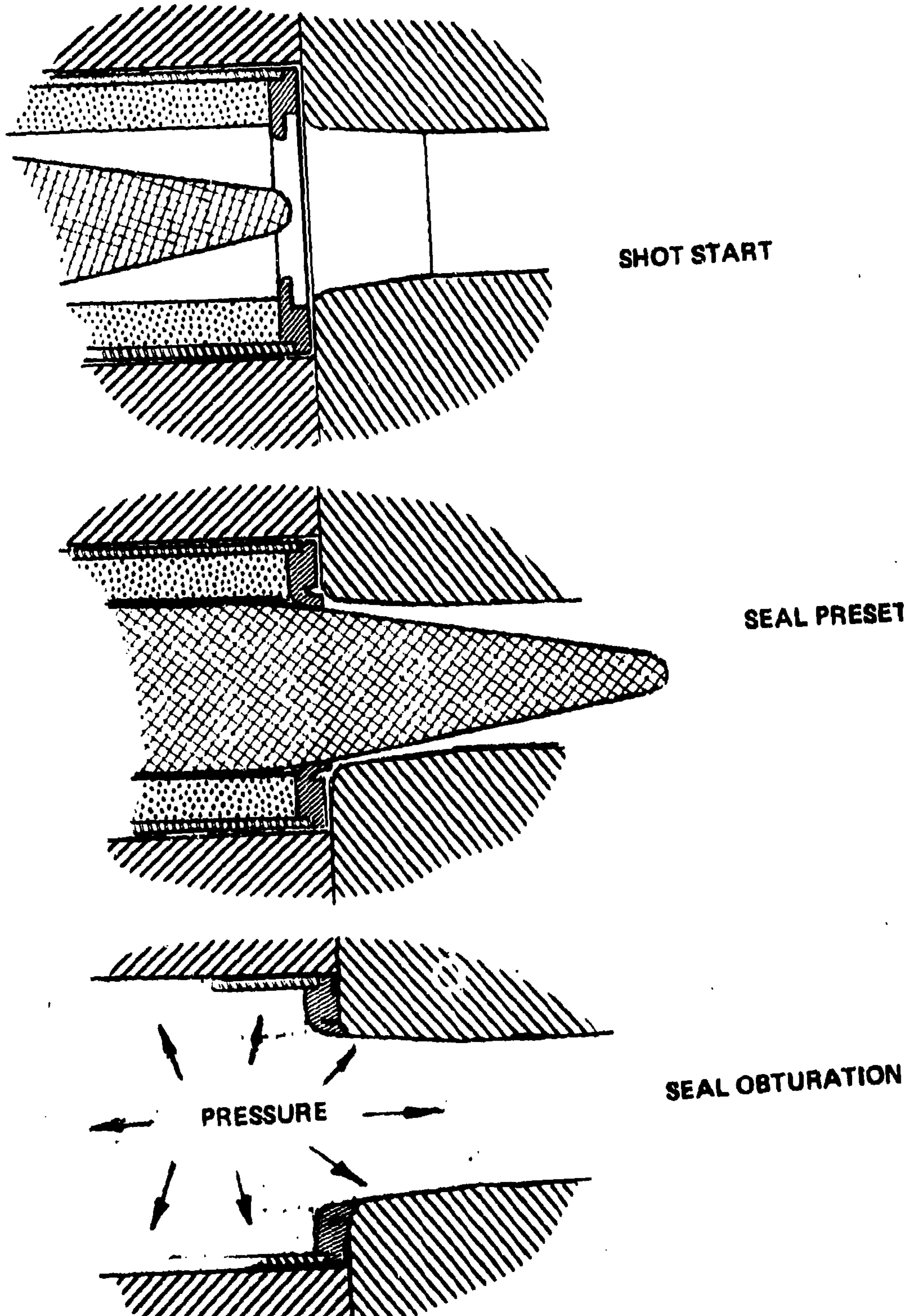


Figure 11. Interface Seal Concept

2.2.5 Primer. Two types of primers were planned for evaluation. These consisted of the conventional metal (boxer type) and a plastic concept based on the GAU-7/A combustible primer. The metal primer size was controlled by the primer cavity in the Smith & Wesson ignitor case. The primers that were available were the small pistol, small rifle and magnum small rifle. The metal primer construction is characterized by a metal cup containing a primary explosive mix and an anvil. The primer functions by a pinching action imposed by a firing pin impacting the cap and forcing it to squeeze the primer mix against the anvil. The primer mix ignites under the impact force.

A plastic primer was designed for test evaluations. The primer configuration was based on the combustible primer technology developed in the GAU-7/A program. The primer functions similarly to the metal primer by squeezing the primer mix in a confined space. The primer shown in Figure 12 was composed of an outer cup, a split wedge firing pin tip, an anvil, a cover and a small quantity (100 milligrams) of primer mix FA 1061. The mix was located between the firing pin tip and an aperture in the outer cup. The aperture functioned as a flash hole to control the direction of the primer flash into the ignitor booster cavity. A plastic firing pin tip, modeled after the GAU-7/A firing pin, was positioned in the cup to provide a 0.050 ± 0.010 inch standoff above the mix. The primer components were machined from nylon 6/6 and Celcon® rod as shown in Figure 13. The outer cup was dimensioned to fit into the aperture in the case head that was provided for the caliber .32 Smith & Wesson cartridge. The assembly is shown in Figure 14.

2.3 Single Shot Fixture Design.

2.3.1 Brunswick Universal Fixture. The Brunswick Universal Test Fixture is shown in Figure 15. The fixture consists of yoke shaped receiver with threaded inserts at each end. The forward insert and the barrel adaptor supports the barrel and the breech extender and the breech screw provides movement of the breech to engage the chamber. The chamber is completely removed from the receiver to load a cartridge. The loaded chamber is positioned in the receiver and aligned with the barrel and firing pin. The breech screw is threaded forward to engage the chamber and exert a compressive force against the barrel adaptor. The compressive load also provides the desired crush-up of the cartridge case. The cartridge is fired by a dynamic piston actuated hammer that impacts the firing pin. A magnetic sensor recorded the impact of the primer. Piezometric pressure transducers recorded the pressure-time profiles at specific locations in the fixture. Pressures can be recorded at the breech face, mid-chamber, in the barrel six inches from the entrance cone and one inch from the muzzle. The interior ballistic data was recorded on each test and utilized to characterize the effects of components and their interaction muzzle velocity. For test data see Appendix C.

2.3.2 Rock Island Arsenal Mann Barrel. The single shot test fixture design selected for this evaluation was based on the sliding chamber sleeve concept developed by Rock Island Arsenal (RIA) for the AMCAWS 30 cartridge

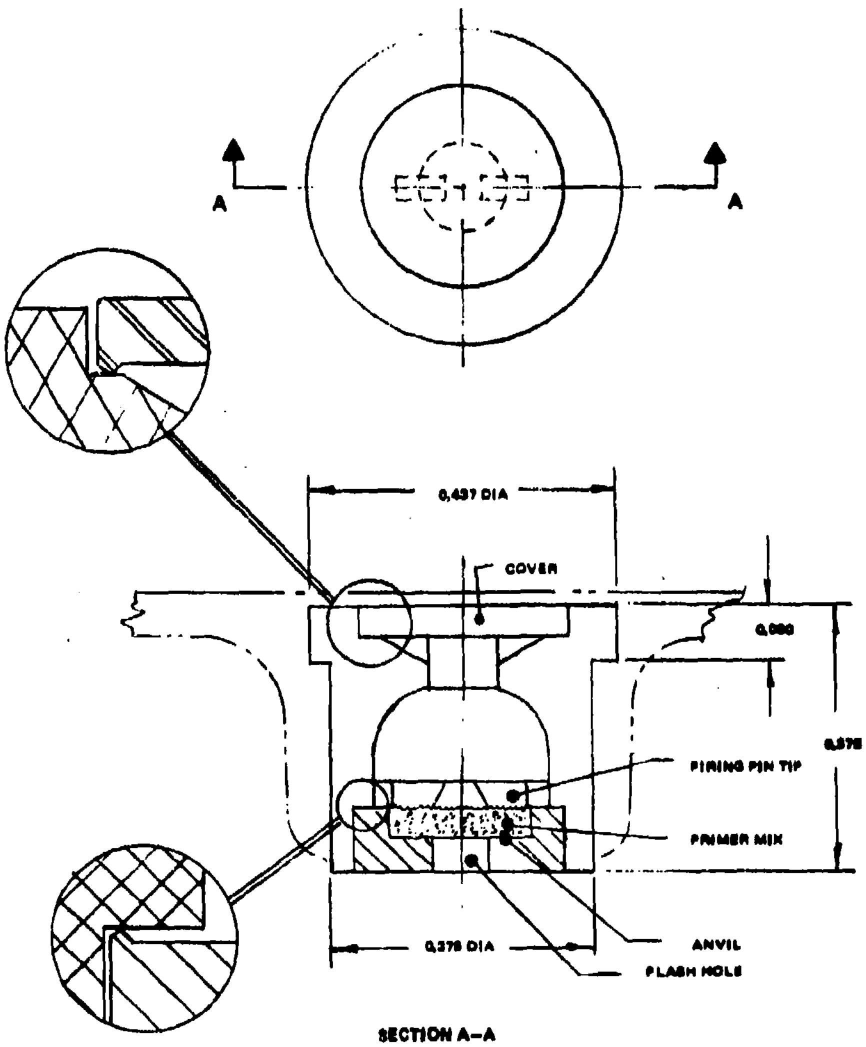


Figure 12. Plastic Primer

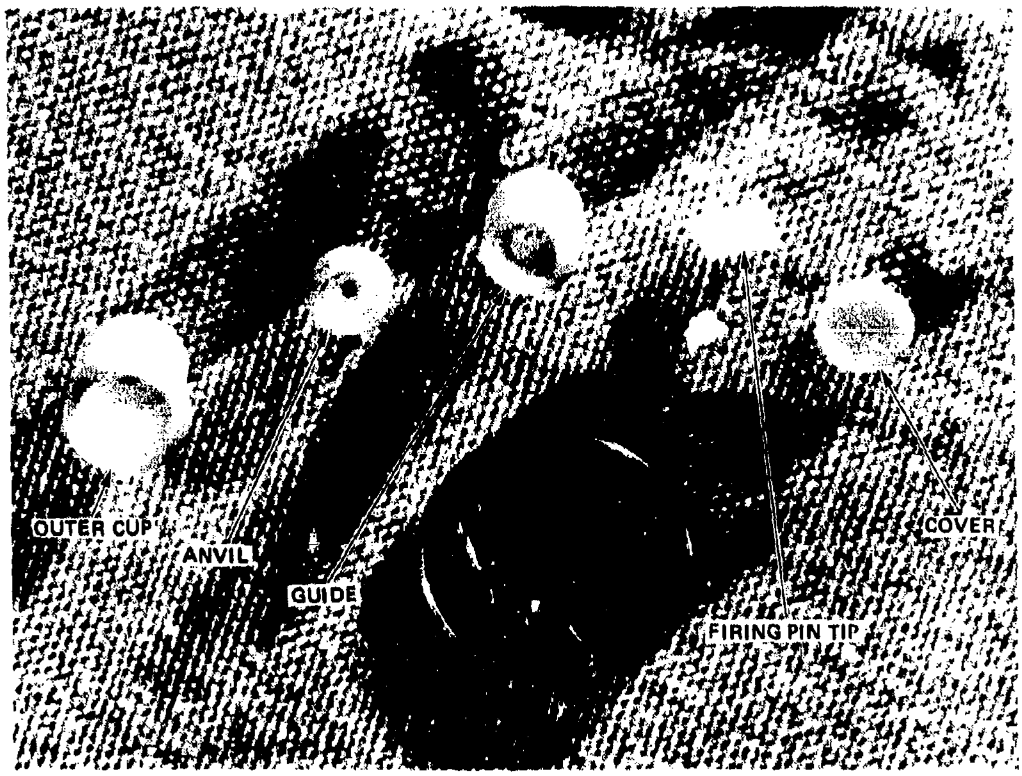


Figure 13. Plastic Primer Components

Figure 14. Plastic Primer Cartridge

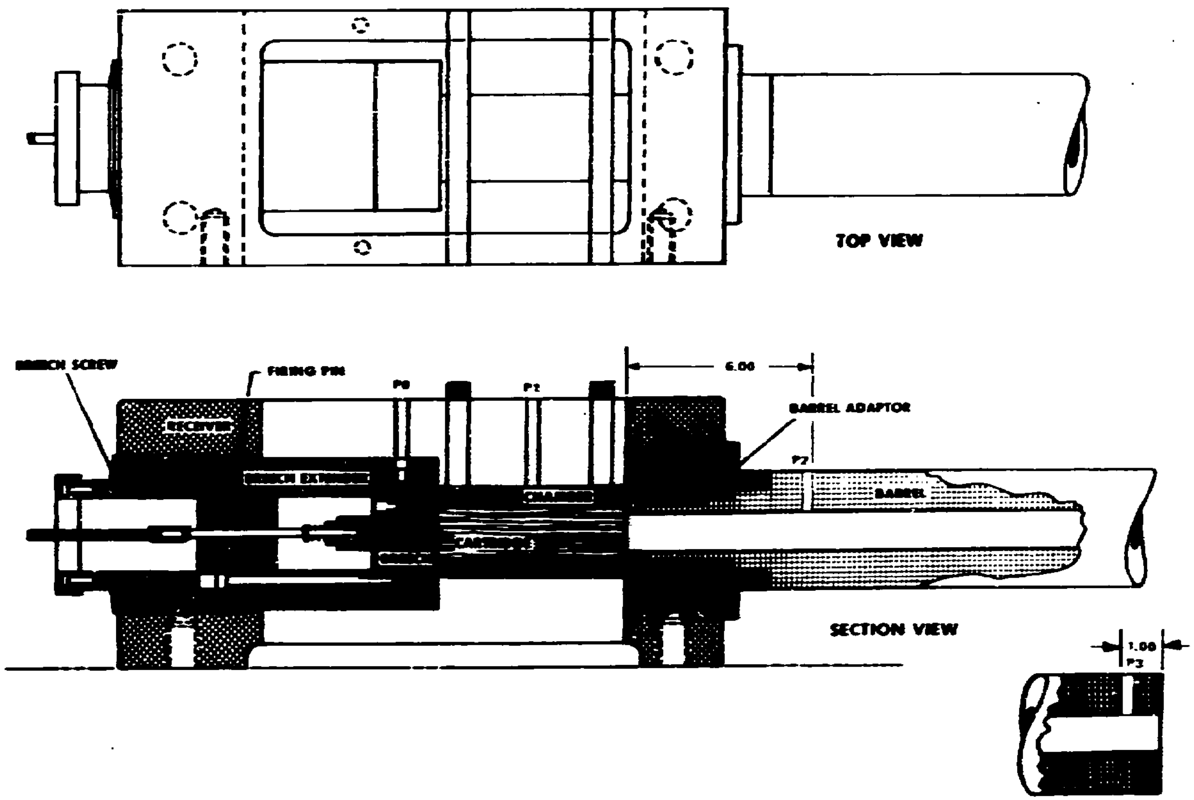


Figure 15. Brunswick Universal Test Fixture

The fixture utilized the reverse taper of the cartridge for alignment with the barrel, cartridge crush-up, and the obturation of the seal prior to firing. The chamber/bolt interface is sealed by an automotive type valve seat developed by GATX for a similar cartridge design under Contract No. F08635-73-0-0003; AFATL-TR-73-220. The plastic case and the RIA gun provided a suitable test vehicle for the shot start studies planned. The fixture is shown in Figure 16.

2.4 GAU-7/A Program Experience

A review of the GAU-7/A ballistic performance results was conducted to determine and establish the requirements for the plastic cased cartridge. The problem areas encountered in the GAU-7/A program were; (i) humidity, (ii) high and low temperature exposure, (iii) thermal growth of the gun, and (iv) seal obturation.

The ballistic results of the GAU-7/A program indicated that the caseless cartridge was compatible with the gun dynamic environment and, with the environmental conditions and with limitations imposed on temperature and humidity, could meet the performance objectives. A revised performance specification was suggested by Brunswick at the conclusion of the GAU-7/A program with limitations on temperature and humidity as follows:

(a) Muzzle Velocity. The mean muzzle velocity shall be $4000 {}^{+200}_{-400}$ feet/second from 50°F to 90°F. A minimum of 65 percent of all rounds fired shall be above the minimum specified velocity as indicated in the paragraph below for temperature variations.

(b) Chamber Pressure. The mean chamber pressure plus 3 standard deviations shall not exceed 75,000 psi, except at temperatures between +100°F and +160°F where the individual chamber pressure shall not exceed 75,000 psi. Individual round pressures of less than 40,000 psi may be excluded in determining $\bar{X}$ and σ, except below 70°F.

(c) Action Time. The mean action time shall be less than 14 milliseconds at any temperature and the individual action time shall be less than 16 milliseconds at temperatures greater than -40°F. For temperatures above 80°F, the mean action time shall not exceed 10 milliseconds and the standard deviation shall not exceed 1.5 milliseconds.

(d) Temperature. The ammunition shall be capable of operation during and after exposure to the following conditions:

(1) Storage Temperature: -80°F to +160°F (protected in shipping container)

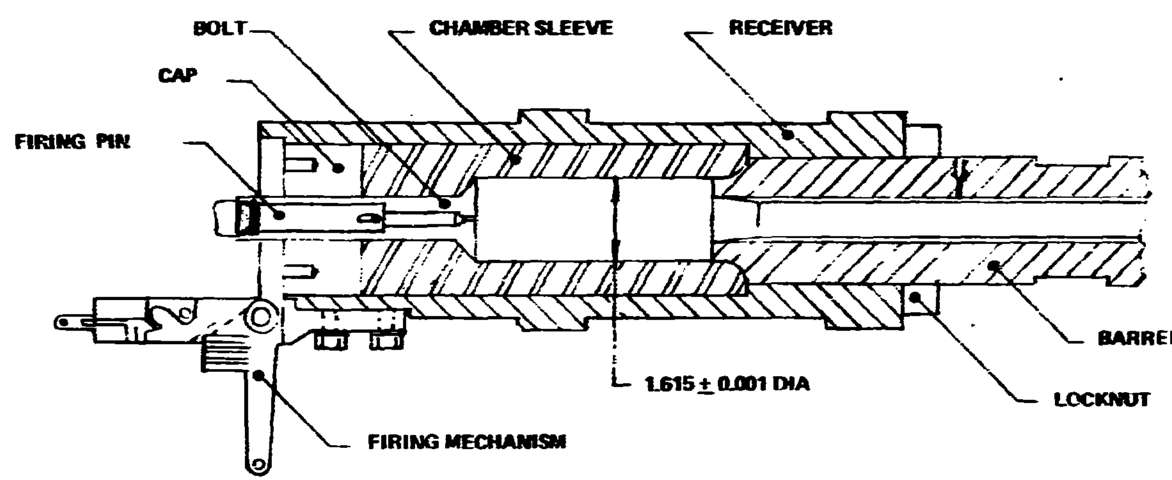


Figure 16. Rock Island Arsenal Mann Barrel

(2) Feed Bay Temperature: $-65^{o}F$ to $+160^{o}F$
(24 hours continuous)

(3) Tunnel Temperature: $-65^{o}F$ to $+160^{o}F$
(30 minutes continuous)

The ammunition muzzle velocity, after exposure to the induced environment (temperature range $-20^{o}F$ to $+120^{o}F$), shall not be degraded more than 10 percent from the low value specified in paragraph 2.4 (a). MIL-STD-810B, Method 501, Procedure I, and MIL-STD-810B, Method 502, Procedure I shall apply. No velocity degradation shall occur due to storage in the shipping container. Between $-20^{o}F$ and $-65^{o}F$, no individual round shall be below 2000 ft/sec. The mean value for all rounds shall be above 2600 ft/sec. Between $120^{o}F$ and $160^{o}F$ no individual round shall be below 2500 ft/sec. The mean value for all rounds shall be above 3000 ft/sec. Sixty-five percent of all rounds will be above 3000 ft/sec.

(e) Humidity. The ammunition shall be capable of operation during and after exposure to relative humidity conditions. This excludes conditions wherein condensation occurs in and on the equipment. MIL-STD-810B, Method 507, Procedure V applies, five cycles only.

The variabilities associated with the GAU-7/A ballistic performance have been identified to be those factors that affect the thermochemical properties of the propellant charges. These properties are related to the ignition and combustion (reaction rate) processes that control the interior ballistics of the telescoped cartridge. The portion of the ballistics that is the most sensitive to these factors is the shot start cycle. This cycle is a sequence of events that moves the projectile to the barrel and ignites the propellant charge. The sequence involves the interaction of several rate dependent functions. These include the action of the primer, the ignitor booster, the projectile retainer, the projectile release, travel and barrel obturation, band engraving, and propellant ignition. The factors that have a significant effect on these functions are:

(1) Temperature

(2) Humidity

(3) Pressure

(4) Gun System Variables. These include chamber seal leakage, barrel wear and growth and chamber and receiver growth.

2.4.1 Temperature Effects. The temperature factor is the heating or cooling of the cartridge which results from changes in environmental conditions. The effect of changes in temperature is observed in rate controlling processes in the shot start sequence. These processes include the function of the ignitor, the retainer, the engraving band, and propellant ignition. Elevated temperatures (120°F to 160°F) accelerate the ignitor's reaction rate, ignition, retainer release, and the projectile engraving process. Low temperatures (-65°F to 20°F) retard these processes. The control of these events is essential to controlling the projectile's travel to the barrel. It is important that the projectile obturate the barrel prior to propellant charge ignition (8000 psi) to prevent propellant from entering the barrel ahead of the projectile. Retarding propellant ignition at an elevated temperature but not a cold temperature is a major problem.

One adverse effect of elevated temperature (120°F to 160°F) on ballistic performance is characterized as propellant blowby (PBB) and typically results in low muzzle velocity (2000 fps), short action time (4.5 ms), and moderatly high chamber pressures (45 kpsi).

Low temperature (20°F to -65°F) produces entirely different ballistic performance. The reduction of heat delays the ignition of the propellant charge. The result can be an extended action time (14 msec), increased muzzle velocity (4100 fps), and increased chamber pressure (75 kpsi).

The effect of low engraving force band materials such as nylon has been shown to induce an additional variation in performance at temperatures from 70°F to -65°F. This type band does not provide sufficient resistance to projectile travel at engraving and the projectile continues into the barrel. The characteristic performance is a range in action times from 10 to 18 msec, low muzzle velocity (2000 fps), and low chamber pressure (20 kpsi).

2.4.2 Humidity Effects. Moisture levels up to 2.5 percent in the propellant charges have been observed to be beneficial in stabilizing the combustion process. The effect is believed to be catalytic and, in reactions involving black powder, the moisture yields a more complete decomposition. However, moisture levels greater than 2.5 percent are detrimental to ballistic performance because the heat of vaporization becomes a controlling factor in the ignition process. Additional energy and time are required to evaporate the moisture and ignite the charge. The performance is similar to the effect of low temperature except that hangfires and misfires can result. The combined effect of humidity and low temperature further complicates the problem, resulting in hangfires and misfires.

2.4.3 Pressure Effects. Pressure is not an environmental factor but rather an internal factor that affects the shot start cycle. Pressure has the primary role of moving the projectile to the barrel. It also has a secondary role in controlling the ignition of the propellant. The propellant combustion (reaction rate) is pressure dependent in addition to being temperature dependent. Pressures in the range of 5 kpsi to 7 kpsi are required to provide stable combustion. Factors in the cartridge and gun that influence the rate of pressure rise will directly affect the ballistic performance. The environmental factors of temperature and humidity affect pressure rise rate through the control of the reaction rate. The engraving band affects projectile travel which is related to pressure control by determining internal free volume. The seals in the GAU-7/A gun have been shown to affect performance by allowing ignition gas to escape. The effect of gas leakage is normally observed as an increase in action time (21 msec) accompanied by propellant blowby producing low muzzle velocity (3000 fps) and low chamber pressure (35 kpsi).

2.4.4 Gun System Variations. Gun system related problems were also observed in multishot burst firings. Ballistic performance variations (increased action times) were recorded that were not observed in single shot firings. The difficulties were identified as thermal effects induced in the gun by the combustible ammunition. The problem areas were:

(a) Chamber and Receiver Growth. The thermal growth of the chamber and receiver was calculated based on a mass average temperature of approximately 900°F. This temperature was considered to be the highest that would occur at the conclusion of a 1000-round burst at full rate with air being forced down the hot barrels. The chamber diameter was estimated to increase from 1.615 inches to 1.625 inches and the chamber length increased approximately 0.040 inch. These changes in chamber dimensions were not anticipated to significantly affect the ballistic performance. The significant dimensional change, however, was observed to occur in the gap between the chamber and the receiver. The thermal growth of the receiver was calculated to yield a gap that was 0.040 inch greater than the nominal 0.020 inch gap at ambient temperature. This increased gap affected the gun chamber seal obturation and the ballistic performance.

(b) Seal Leakage. Gun seals were incorporated at each end of the chamber to obturate with the barrel at one end of the chamber and with the receiver at the other end. The seals were captured but could expand radially and move longitudinally to the chamber. Seal motion and closing depended entirely on pressure generated by the combustible ammunition. A gas leak existed until the local pressure reached 8000 psi. A seal requiring 8000 psi for complete obturation indicates that a variable gas leak will exist for the duration of the shot start cycle. The radial expansion of the seal provided a gas seal in the seal cavity and the longitudinal seal movement compensated for tolerance differences between gun chambers and the receiver. The longitudinal distance the seal moved was a function of chamber, receiver, and seal temperatures as well as initial clearances due to tolerancing. Because of significant differences in mass and heat flux, the seal, chamber, and receiver did not heat and expand in consonance with one another, and seal performance varied correspondingly during a burst of 150 rounds.

The ignitor components of the shot start cycle will tolerate small changes in leak rates but, because their thermochemical properties are pressure dependent, seals that fail to close have a significant influence on ballistic performance. A leaking seal will produce the category of performance known as delayed ignition accompanied by propellant blowby with action times up to and exceeding 21 milliseconds.

(c) Barrel Wear and Growth. The effect of barrel wear and diametrical thermal expansion of the entrance cone has a direct influence on the projectile engraving properties. Variations in the projectile position will affect the free volume and the propellant ignition process. Barrel wear and growth will result in increased and variable action time (8 to 14 msec), decreased and variable muzzle velocity (3500 fps to 2500 fps) accompanied by variable chamber pressures (45 kpsi to 25 kpsi). The magnitude of the performance degradation will depend on the engraving loads which in turn depend on the geometry and material of the rotating band and the barrel's internal geometry. Variations due to thermal growth will be more significant in rapid firing gun systems.

SECTION III

DEVELOPMENTAL TESTING

3.1 Background.

The results of the GAU-7/A Phase IV ammunition development program identified the major problem areas associated with the ballistic performance. These areas were the environmental conditions of humidity at the temperature extremes of -65°F and 160°F and the multishot gun variables associated with thermal growth and leaking chamber seals. It was believed that solutions to these problems could be achieved through design changes in both the cartridge and the gun.

The replacement of the GAU-7/A combustible case with a plastic case eliminates a temperature and humidity sensitive component from the shot start cycle. The plastic case will not provide a moisture-proof cartridge but resistance to the humidity environment will be improved. The plastic case will reduce thermal heating of the chamber that will result in closer dimensional tolerances which will improve the chamber/barrel seal interface significantly. The replacement of the combustible primer with a conventional metal primer will eliminate the need for firing pin seals and prevent pin tip erosion. The metal flash tube that supports the primer and houses the ignitor charge will provide directional control of the ignitor gases that was not possible in the GAU-7/A cartridge.

The incorporation of a chamber seal in the cartridge ensures that the gas seal at the chamber/barrel interface is positioned prior to firing. The ability to seal the chamber independently of pressure eliminates the most significant GAU-7/A gun variable. The cartridge seal provides chamber obturation similar to the technique utilized in conventional cased ammunition. The elimination of the variable seal leakage rate will permit shot start studies to be conducted under more controlled conditions.

3.2 Development Test Plan.

The test plan was directed at establishing the cartridge configuration for the 2500 rounds of deliverable ammunition. The specific areas to be evaluated were the ignition (booster) charge, the molded propellant charge, the cartridge case material, and the cartridge seal design configuration and material. Five hundred Mann barrel tests were planned to observe the effects of temperature, humidity, propellant and hazard environmental exposure on the ballistic performance of the cartridge. The baseline cartridge configuration selected for these studies consisted of the forward charge; aft charge and a nitrocellulose retainer. The component changes were minimized to keep the number of variables as small as possible. The component variables that were permitted to change were (i) the propellant relative quickness and charge weight, (ii) the booster composition, (iii) granulation, and charge weight, (iv) the primer type, (v) the cartridge case material, and (vi) the cartridge seal configuration and material.

3.3 Component Evaluations.

3.3.1 Propellant Charge. The propellant charges evaluated were fabricated from GAU-7/A propellant lots 5479, 5473, 5472, 5463, and 5440 from Canadian Industries Limited (CIL) and 8446-9 and 8472-1 from E. I. duPont de Nemours and Co., Inc. The relative quickness (RQ) of these lots ranged from 90 percent to 104 percent of the GAU-7/A standard propellant, CIL lot 5425. The propellant charge weights ranged from 126 grams to 143 grams. The average aft charge weight was 45 grams for all the tests.

Ballistic tests (See Appendix C, Test Serial Nos. 1, 2, 3, 4, 8, 9, and 10 [55 rounds]) were utilized to establish the propellant charge requirements. The test series resulted in a complete spectrum of ballistic performance from high pressure stop mode to low pressure blowby behavior. Stop mode behavior is defined as occurring when a rapid ignitor propels the projectile disproportionately faster than it ignites the propellant, causing the engraving resistance of the barrel to stop the projectile momentarily until a pressure rise created by further flame speed can again accelerate the projectile. Low pressure blowby is a condition of under-ignition which accelerates the projectile so slowly that gas reaches the barrel ahead of the projectile. The results of the tests indicated that several combinations of charge RQ and weight would meet the GAU-7/A performance specification at ambient conditions. For example, the ballistic performance of a 104 RQ charge at a weight of 126 grams was similar to the performance of a 95 RQ charge at a 136-gram weight. The significant differences were observed in the ballistic action times, with the shorter time (4.5 to 6.5 ms) associated with the 104 RQ propellant. The occurrence of blowby performance was observed to be 60 percent greater with the 104 RQ propellant than with the lower RQ propellant. GAU-7/A experience demonstrated that increased cycle times occurred at low temperatures with low RQ propellant and that increased muzzle velocity variations would result at elevated temperatures with high RQ propellant. A compromise charge was selected to assure as wide an operational temperature range as possible. The baseline propellant charge was established to have a relative quickness at 98 ± 2 percent and an average charge weight of 130 ± 2 grams. The anticipated GAU-7/A performance goal could be achieved but action times would range from 7 to 10 milliseconds. The results of the ten best tests utilizing baseline components are shown in Table 2.

TABLE 2 - TEN BEST TEST RESULTS

	Chamber Pressure (KPSI)	Muzzle Pressure (KPSI)	Muzzle Velocity (FPS)	Action Time (MS)
$\bar{x}$	55	7.0	3890	8
σ	5.3	0.9	140	1.7

A typical pressure-time record is shown in Figure 17.

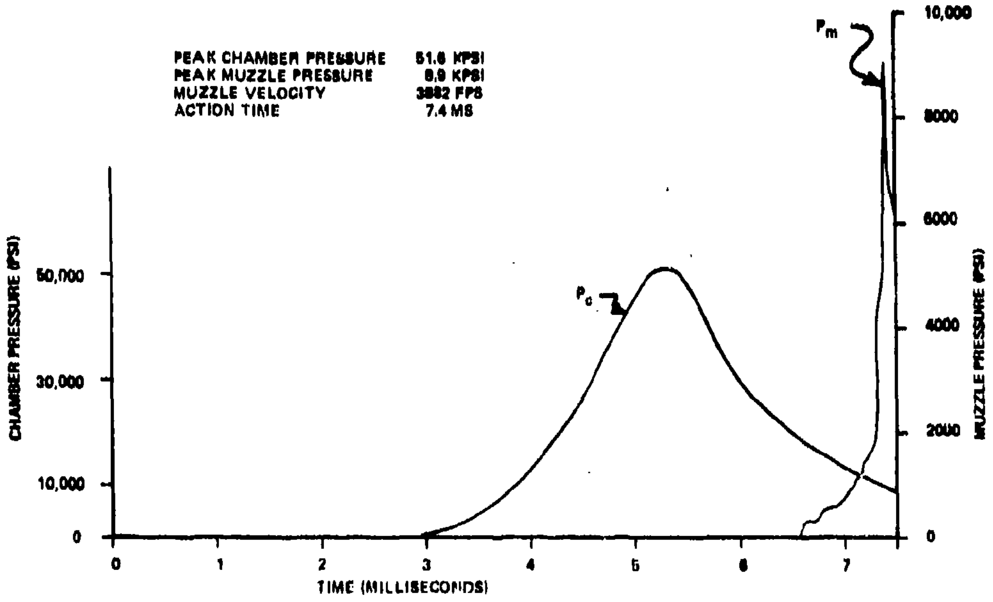


Figure 17. Computer Print-Out of Pressure Versus Time Record

3.3.2 Ignitor. The ignitor compositions selected for evaluation were based on their performance in the GAU-7/A program and recommended for continued evaluation. These materials included black powder Class 3 and Class 6; Flare Northern's Titanium-barium nitrate; and McCormick Selphs' compositions 300432 and 300439. The charge weights of each material could range from 0.1 gram to 1.5 grams depending upon the granulation and purposes of the ballistic test. Vendors are listed in Appendix B.

Ballistic tests (See Appendix C, Test Serial Nos. 1, 2, 3, 4, 5, and 15 [44 rounds]) were conducted to establish the baseline ignitor. The energetic ignitors that were successful in the GAU-7/A program did not perform successfully because of the absence of the gun seal leak. These ignitors were represented by the Flare Northern and the McCormick Selph materials. Test results demonstrated that the cartridge was less sensitive to small changes (0.05 gram) in ignitor charge weight when black powder was used. The baseline ignitor charge weight selected was 0.75 ± 0.05 gram of Class 3 black powder.

3.3.3 Primer.

3.3.3.1 Plastic Primer. The development of the plastic primer was limited to ball drop sensitivity test evaluations because the Brunswick Universal Test Fixture was not capable of delivering the required impact energy and the Rock Island Gun was not fabricated at that time in the program.

A standard ball drop test apparatus was used to evaluate primer designs and determine the initiation energy. An illustration of the ball and the primer simple test tool is shown in Figure 18. The ball drop plastic primer test hardware dimensions are shown in Figure 19. The primer components were designed for ease of manufacture and for convenience in evaluating the critical variables associated with initiation energy, primer mix composition thickness and cup dimensions. No attempt was made to retain the firing pin or to recess the primer in the case. The results of the evaluation demonstrated that a plastic primer would withstand the primer mix explosion and provide directional control of the output jet of gas. The initial energy was shown to be dependent on the anvil hardness, mix thickness, and firing pin travel distance. The anvil material selected was nylon 6/12, 43 percent glass, the primer mix thickness was 0.010 inch to 0.025 inch, and the firing pin tip minimum standoff was determined to be 0.050 inch. The plastic primer demonstrated that the initiation energy at ambient conditions was 250 inch-ounces. A minimum hardness value for the anvil and pin tip were selected at a Shore D of 84.

3.3.3.2 Metal Primer. The initial gun firing tests were conducted with caliber .32 Smith and Wesson brass cartridges. These cartridges contained pistol primers. The gun tests showed repeated occurrences of primer cap perforation. To eliminate the hole in the cap, small rifle primers were evaluated. Two energy levels were selected - the standard small rifle primer and the magnum small rifle primer. Both rifle primers were manufactured by Cascade Cartridge, Inc. (CCI) and were identified as No. 400 and No. 450 M, respectively.

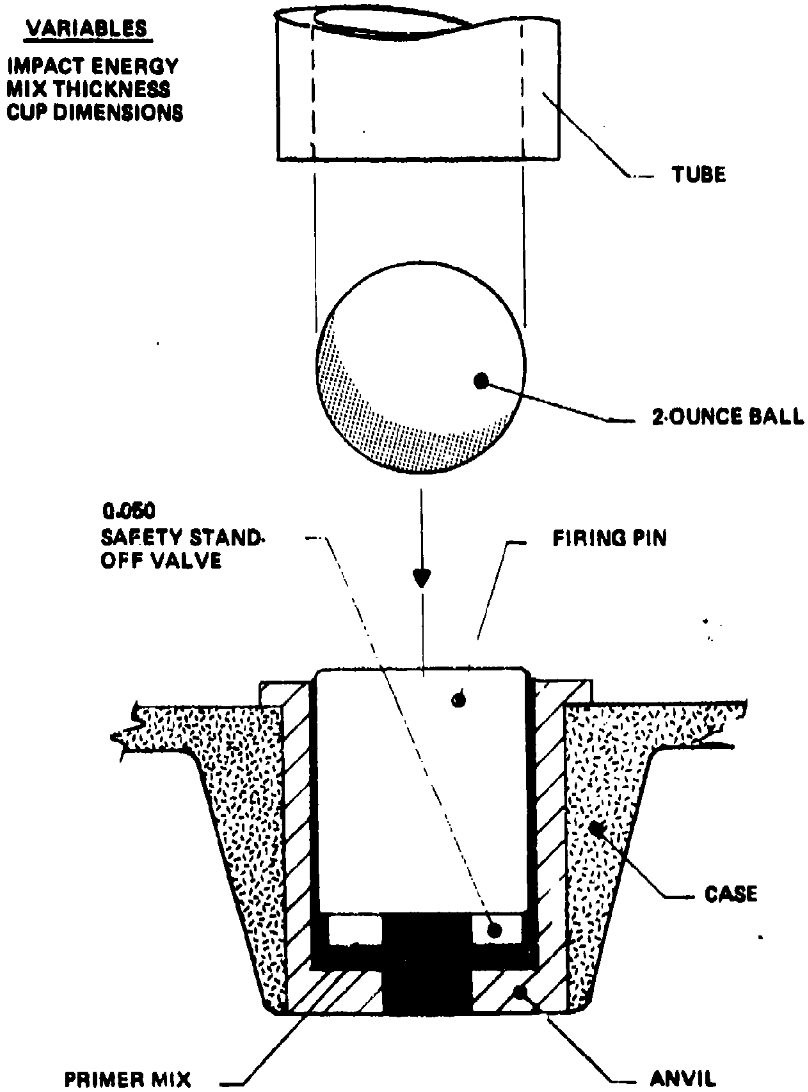


Figure 18. Plastic Primer Configuration Study

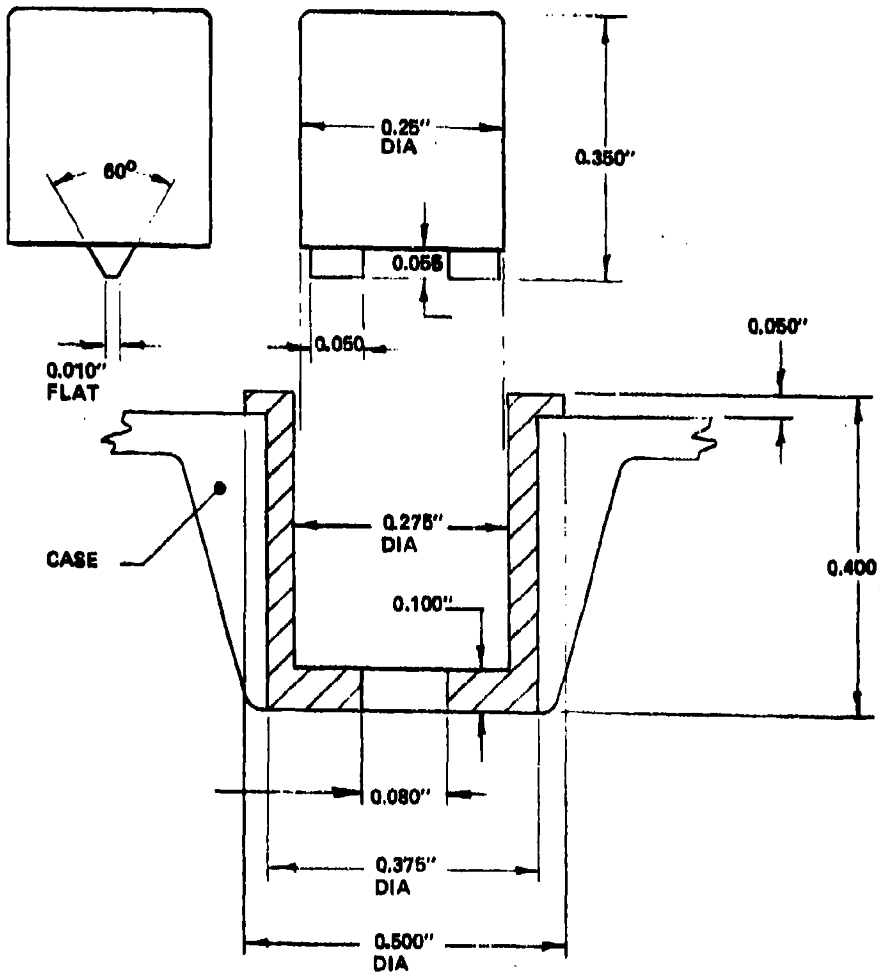


Figure 19. Ball Drop Plastic Primer Test Hardware

Fifteen rounds (See Appendix C, Test Serial No. 19) were tested to compare the performances of the two types of rifle primers with the pistol primer. The results of the tests indicated that there was no significant difference between the pistol and the small rifle primers. Increased performance variability was observed with the magnum primer. Based on these results, the small rifle primer was selected for the baseline cartridge and used in all subsequent tests.

3.3.4 Cartridge Case. Four cartridge case material formulations were evaluated in the ballistic environment. Three materials were injection molded from 33 percent glass filled nylon 12 (Hüls 1938) and 43 percent glass reinforced nylon 6/12 (DuPont 77G43). The fourth material was an epoxy glass filament thermoset. The case materials were evaluated concurrently with the studies to establish the propellant charge, the ignitor, the primer and the seal. The results of 133 cases evaluated at ambient conditions and 30 cases at -65°F can be found in Appendix C, Test Serial Numbers 1 thru 19, inclusive.

The results of the ballistic test evaluations indicated that the DuPont 77G43 cases had a greater tendency to fail by cracking than did the Hüls material. A typical case failure is shown in Figure 20. The crack can be observed to proceed across the case head and longitudinally down the case side wall. The charred white areas adjacent to the crack represent the gas flow path. The gas flow was restricted to the vicinity of the crack because the remaining surface of the case obturated the gun chamber. The impression observed in the case head was a result of the plugged breech pressure aperture. The case did not fail at this point.

The mechanism of the case failure was determined by cross sectioning several of the failed cases. The crack was observed to originate at location "A" at the interface between the caliber .32 Smith and Wesson (S&W) cartridge and the open end of the shoulder supporting the cartridge in the case head. The failure is shown pictorially in Figure 21. It should be noted that the expanded portion of the S&W cartridge secures the cartridge to the plastic case to prevent separation after firing. The figure also shows the extension of the plastic shoulder past the thick portion of the S&W cartridge head.

Am improved design of the plastic case head (shown in Figure 22) would limit the plastic shoulder interface and still provide the lock-in feature desired. This modification was not evaluated but the concept is recommended for a re-evaluation of the DuPont 77G43 case material. It is believed that the DuPont cases will be compatible with the ballistic environment with this design modification.

Cartridge cases (See Appendix C, Test Serial Nos. 1, 2, 3, 4, 5, 10, 11, 12, 15, 16, 17, 18, and 19) made from Huls 1933 and 1938 materials were demonstrated to respond satisfactorily to the ballistic environment at ambient temperature and at -65°F. Several cases were exposed to peak chamber pressures in excess of 100,000 psi. No cracks were observed in any of the tests and each of the cases was extracted without difficulty

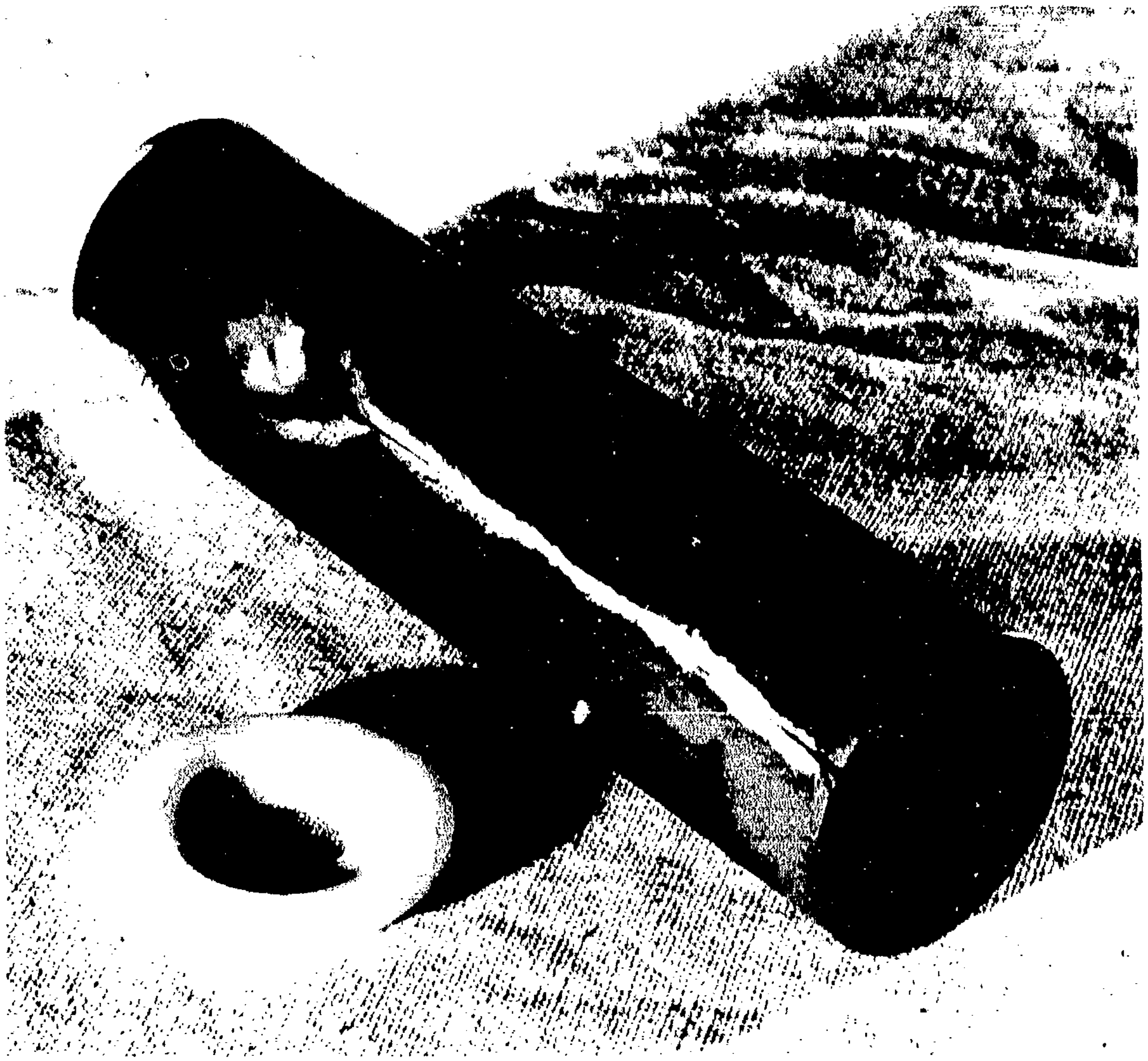
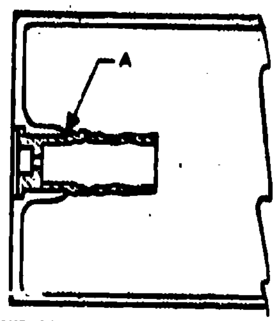


Figure 20. Typical DuPont 77G43 Case Failure

FIRED SMITH AND WESSON CARTRIDGE



POINT OF CRACK ORIGIN A

Figure 21. Case Failure Cause

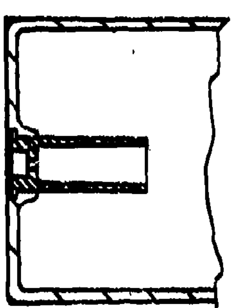


Figure 22. Ignitor/Case Interface Modification

from the gun chamber. Cases of each material were evaluated in the universal test fixture. Typical Hüls 1938 cases before and after ballistic exposure are shown in Figures 23 and 24, respectively. The cartridge case behavior in Figure 24 was typical for peak chamber pressures up to 80,000 psi. Peak pressures in excess of 80,000 psi would result in plastic flow of the seal into the gap at the chamber/barrel interface as shown in Figure 25. The Hüls 1938 material was demonstrated to be compatible with the ballistic environment at -65°F as shown in Figure 26. Based on the results of these evaluations and the supply of the raw resin material, Hüls 1938 was selected as the case material for the delivery ammunition.

Cartridge case crush-up experiments were conducted to evaluate the effect on case performance. Cartridges were fabricated to chamber length (6.055 inches) and in 0.025 inch increments longer than the chamber up to 0.1 inch. The cartridges were placed in the universal test fixture and crushed by threading in the breech until the breech engaged the chamber. The cartridges were fired and the cases extracted for examination. The cases that were 0.075 to 0.1 inch longer than the chamber cracked at the base corner during crush-up. The crack provided a gas leak in the ballistic cycle that resulted in a burn on the chamber face and charring of the outer surfaces of the case (Figure 27). The cartridges that were chamber length did not obturate at the forward end and combustion gases charred the exterior of the case and eroded the seal (Figure 28). Satisfactory chamber obturation was achieved with crush-up distances of between 0.025 inch and 0.050 inch. The crush-up distance selected for the baseline cartridge was 0.040 ± 0.010 inch.

Limited testing was performed with the epoxy/glass cases shown in Figure 29. The ballistic performance data was very uniform but extraction from the gun was complicated by the over-stressed steel head and seal. The thermoset material appeared to function without damage. The tests were disqualified because of the gas leak at the head/case and seal/case interfaces. The cases were fabricated to be chamber length (6.055 inches). There was no crush-up force exerted on the cartridge. The average of two ballistic performance tests results are shown below:

Chamber Pressure (KPSI)	Muzzle Pressure (KPSI)	Muzzle Velocity (FPS)	Cycle Time (MS)
48	6.2	3529	4.8

The uniform ballistic performance was determined to be the result of the projectile impacting the metal seal and simulating the high engraving loads normally observed with copper banded projectiles. The abrupt deceleration of the projectile is normally sufficient to trigger the propellant ignition and the subsequent events that evolve into a desirable ballistic cycle.

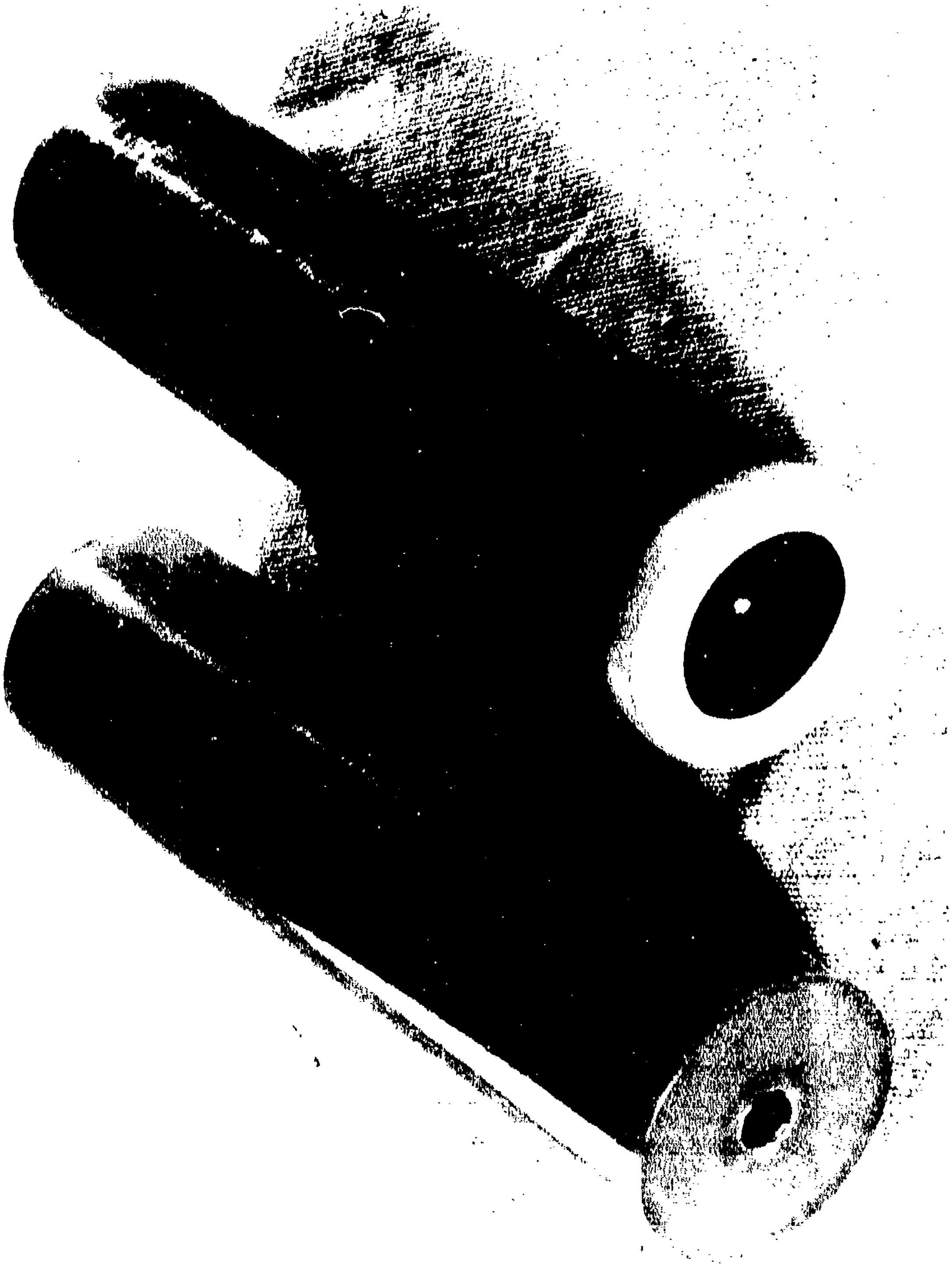


Figure 23. Hüls 1938 Cases Before Firing

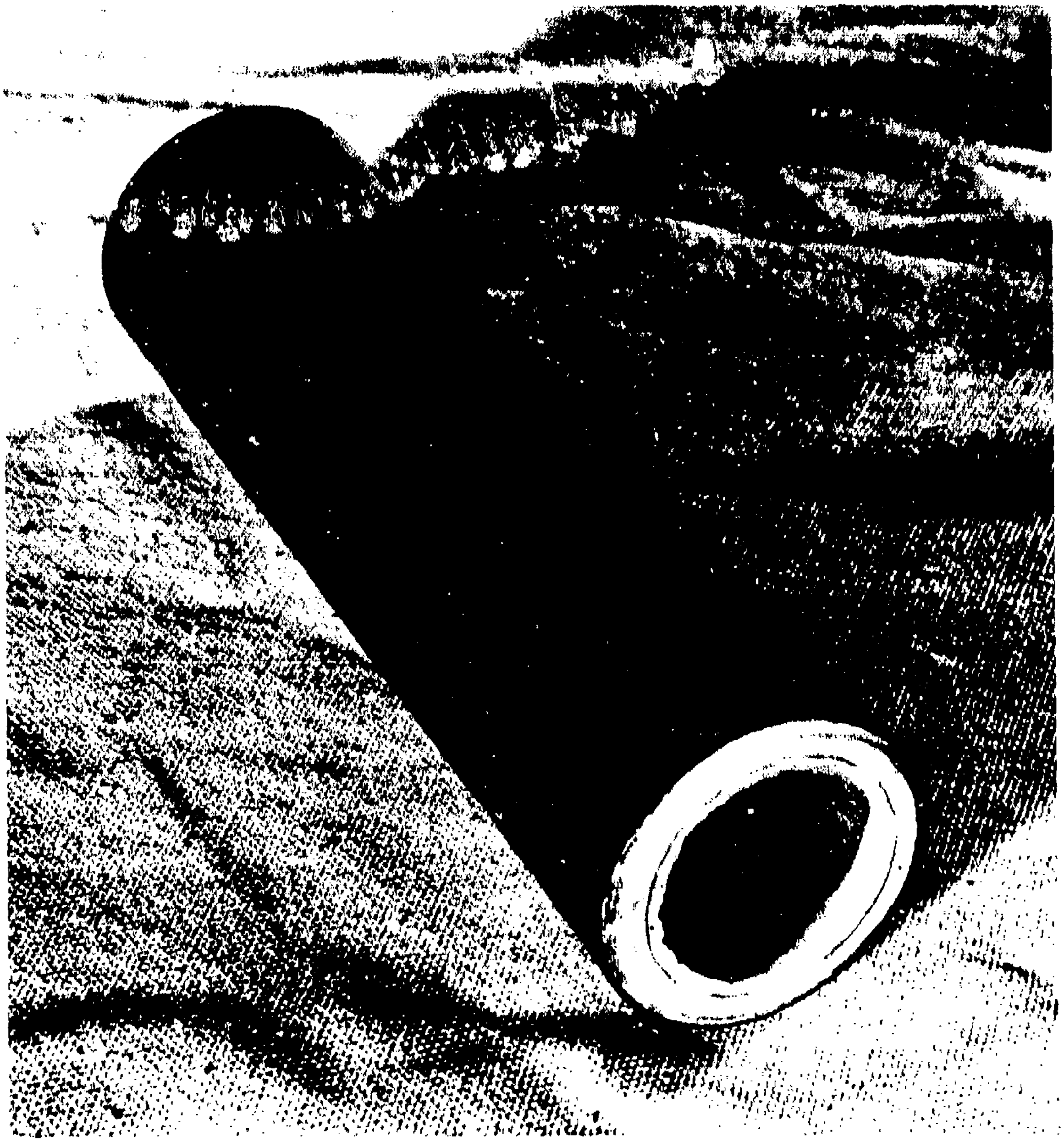


Figure 24. Hüls 1938 Case After Firing

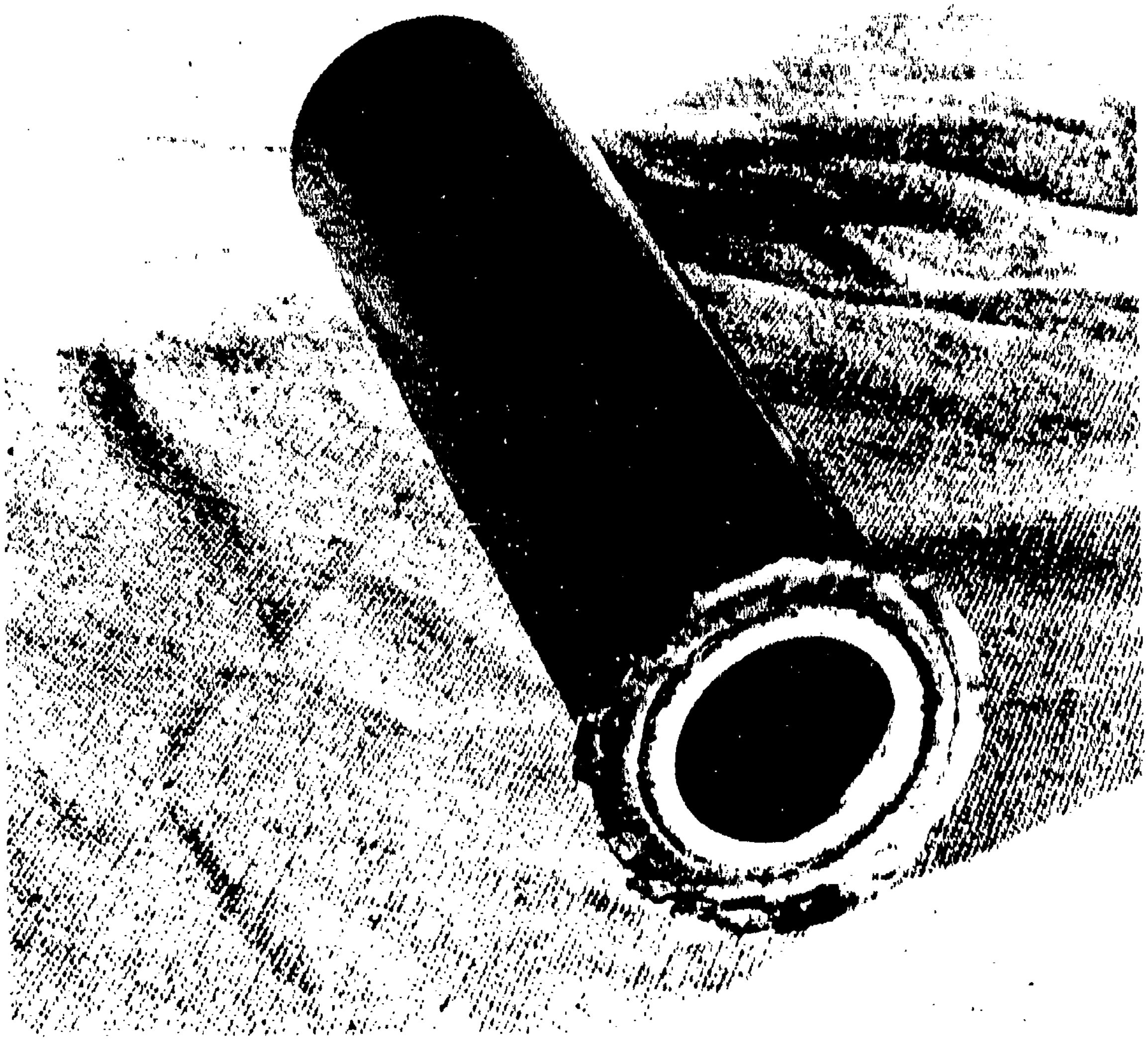


Figure 25. Hüls 1938 After Exposure to 100,000+ psi

Figure 26. Hüls 1938 Case After Exposure to 53,000 psi at -65°F

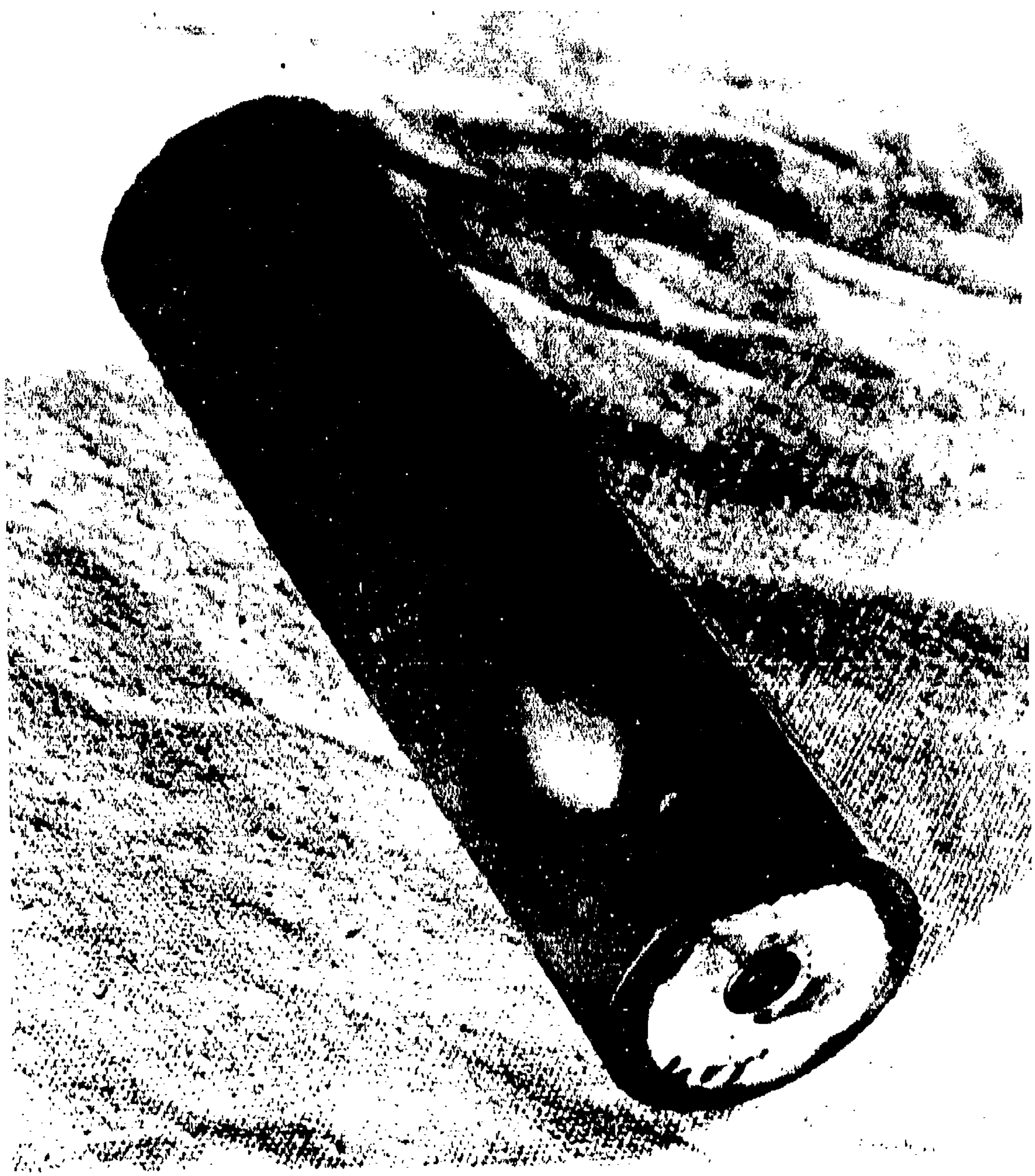


Figure 27. Hüls 1938 Case 0.1 Inch Crush-up

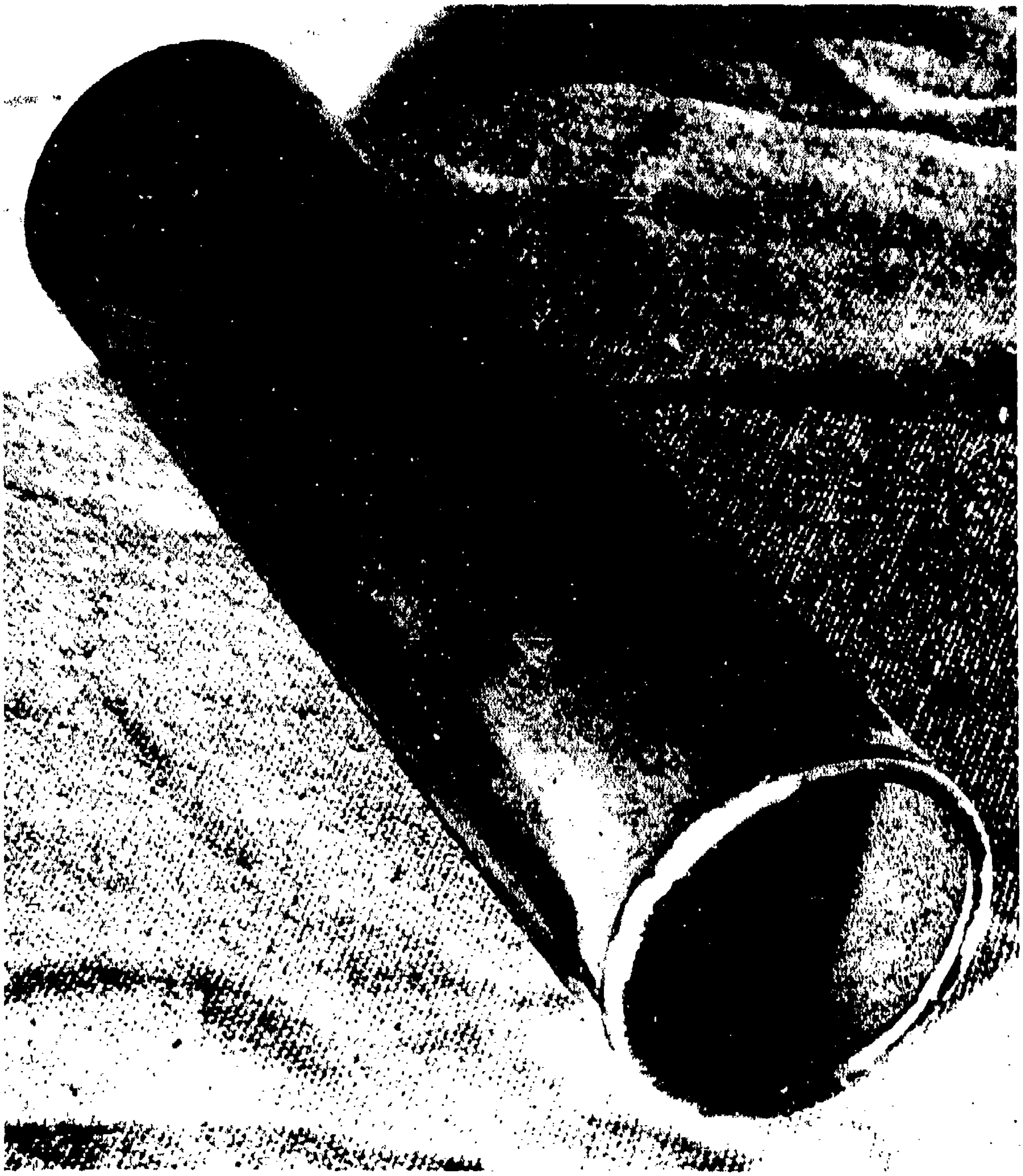


Figure 28. Hüls 1938 Case No Crush-up

Figure 29. Epoxy-glass Fiber Composite Cartridge Case

3.3.5 Chamber Seals. The chamber seal investigation originated with metal seals made from steel and brass. Ballistic performance with the seals demonstrated significant improvement and reduced variation when compared to tests without seals or where seals failed to obturate the chamber. The ballistic results of tests with and without seals are shown in Figure 30. The performance is compared to GAU-7/A lot acceptance data.

The two seal tests shown were made with identical charge components. The only difference was with chamber seal. The parameters that reflected the seal performance were muzzle velocity and the variation in velocity. The reduction in ballistic action time from 5.3 to 4.5 milliseconds was the result of an over-ignition condition that existed as a result of a sudden reduction in the rate of volume increase when the projectile impacted the seal. The deformation is shown in Figure 31 with a brass washer seal. The seal configuration before the test is shown adjacent to the cartridge. In all tests of this type the projectile was damaged and the rotating band was torn away on one side. In addition to the damage to the projectiles, the metal seals were difficult to bond to the cases and the cases failed at the seal interface because of the large differences in mechanical properties between the two materials.

It was determined that plastic seals with mechanical properties that were similar to the case material would be desirable candidates as substitutes for the metal seals. Several plastic materials were selected for evaluation. The materials were machined from solid rod or flat sheets into three geometric shapes. The cross section selected was in the form of a triangle as shown in Figure 32 and in Appendix A.

The materials selected were cast nylon, acetal copolymer (Celanese Celcon®), nylon 6/6 (DuPont Zytel® 151), 43 percent glass reinforced nylon 6/12 (DuPont Zytel® 77G43), acrylonitrile-butadiene-styrene (Borg-Warner, Cycopac®) and a polyamide-imide (Amoco, Torlon® 4203). The nylon seals were solvent bonded to the nylon case with m-cresol containing ten percent by weight Zytel® 77G43 resin. The non-nylon seals were adhesive bonded with Pliobond® 20. The cartridge cases were evaluated with a 0.050 inch crush-up. The cartridges were fired and the cases were removed from the gun for examination. The seals that were made from nylon and bonded to the case with m-cresol were superior to the other material candidates. Seals failed as a result of weak bond (Figure 33) joints, configuration, or material properties. The cast nylon seals were eroded by the combustion gas and could not be examined. The acetal was also eroded and gave evidence of an early gas leak by the charred case (Figure 28). The section of the seal remaining was thermally welded to the case. The ABS and the polyamide-imide seal obturated the chamber satisfactorily but the seal was not bonded to the case subsequent to the firing and the seal failed. Ten percent of the Zytel® 77G43 seals cracked due to insufficient elongation (Figure 34). The Zytel® 151 seal was satisfactory in all tests and was selected for the baseline cartridge. The triangle seal geometry was demonstrated to be most compatible to the ballistic environment and that configuration was selected for the delivery ammunition.

NO SEAL

N		Chamber Pressure (KPSI)	Muzzle Pressure (KPSI)	Muzzle Velocity (FPS)	Action Time (MS)
10	X	46.3	4.9	3176	5.3
	σ	5.3	0.7	249	0.4

METAL SEAL

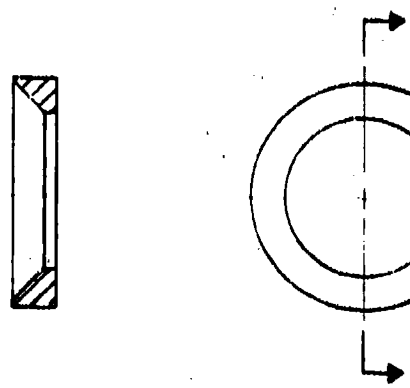
5	X	53.6	5.0	3485	4.5
	σ	6.5	1.0	48	0.5

GAU-7/A

150	X	50.1	7.0	3897	7.5
	σ	6.2	0.9	132	1.2

Figure 30. Ballistic Performance

Figure 31. Brass Seal Impacted by Projectile



MODEL A

Figure 32. Plastic Seal Chamber Geometry

Figure 33. Seal Failure - Weak Case Bond

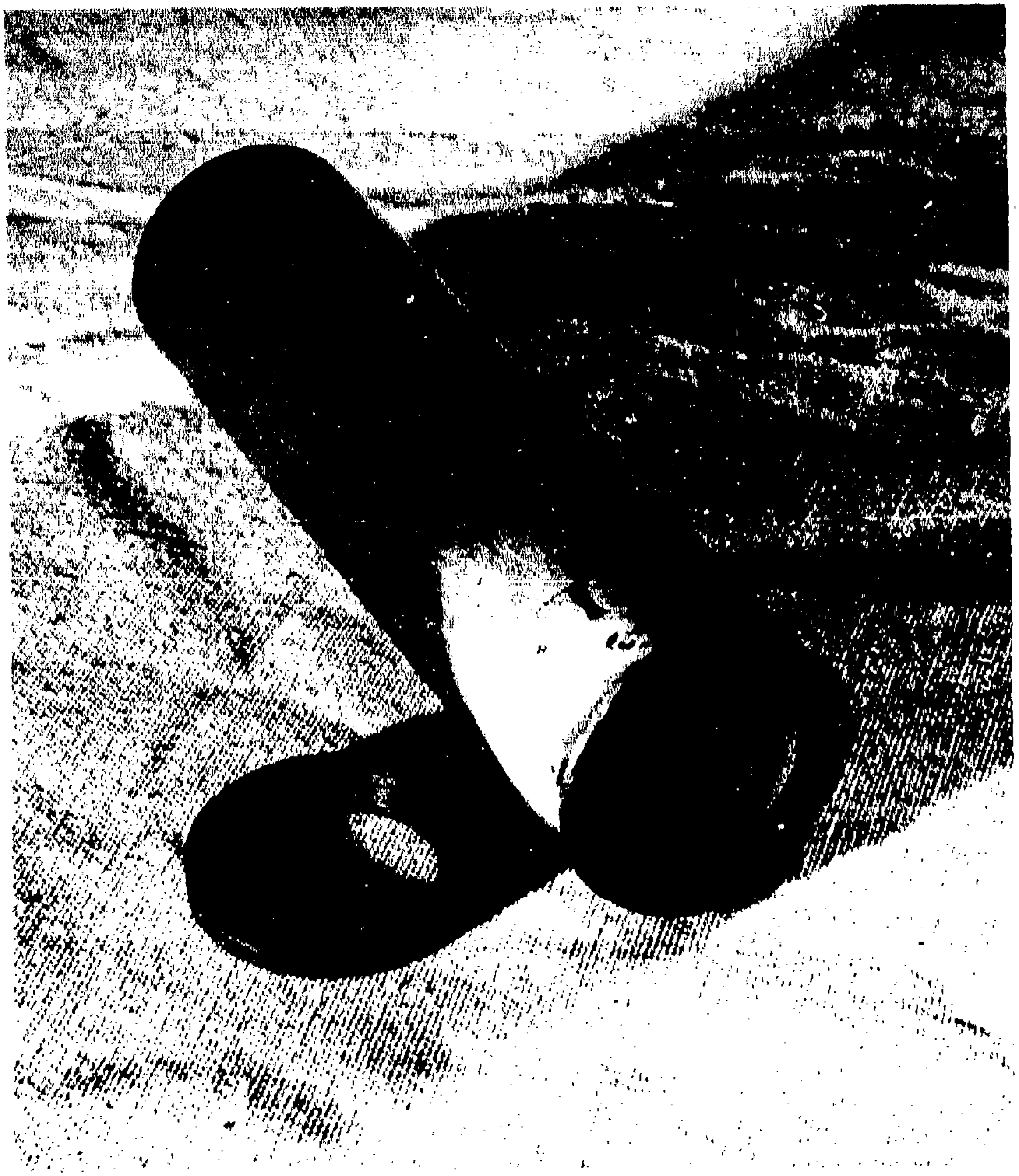


Figure 34. Stress Cracks Indicate Brittle Material

The interference seal/projectile concept was evaluated because of the metal seal ballistic results. Celcon® was selected for this evaluation because of its high impact toughness. The seal failed to obturate in the early part of the ballistic cycle because of a poor case bond and the tests were inconclusive. A repeat study is recommended with a nylon material.

3.3.6 Cartridge Closure. A 3M Company heat sealable aluminized polyethylene terephthalate-polyethylene laminated film (Scotch-Pak® 20) was evaluated as a closure with the cartridges subjected to -65°F. The unsupported portion of the closure became concave during the cold exposure, indicating a reduced pressure was maintained inside the case. The closure did not appear to interfere with the ballistic performance and no debris was observed downrange. This material was selected in a 3.5-mil thickness for the delivery ammunition.

SECTION IV

CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions.

(a) The feasibility of a plastic cartridge case utilizing molded propellants and a telescoped projectile has been demonstrated successfully at ambient conditions and at -65°F.

(b) Experimental investigations have shown that the cartridge case will withstand peak chamber pressures greater than 100,000 psi and extract from the gun chamber without difficulty.

(c) The feasibility of an all plastic primer has been demonstrated.

(d) The chamber seal has been observed to have a significant effect on ballistic performance and a compatible plastic seal has been demonstrated successfully at peak chamber pressures up to 80,000 psi.

(e) The manufacturing feasibility of a zero draft, injection molded case has been demonstrated successfully.

(f) The plastic case provides the potential to minimize the ballistic performance deficiencies of the GAU-7/A program.

(g) The feasibility of a push-through or push-out cartridge case ejection has been successfully demonstrated in a single shot fixture.

(h) The cartridge case and seal materials that were demonstrated to be most compatible to the ballistic environment were Hüls® 38 percent glass filled nylon 12 and DuPont Zytel® 151 (nylon 6/6).

4.2 Recommendations For Follow-on-Work.

(a) Ballistic development of the shot start cycle to minimize the temperature dependence of the ammunition.

(b) Establish the cartridge configuration to comply with the GAU-7/A performance requirements.

(c) Determine, by test, the ballistic performance over the temperature range of -65°F to 160°F.

(d) Develop an automatic test fixture to provide multishot environments.

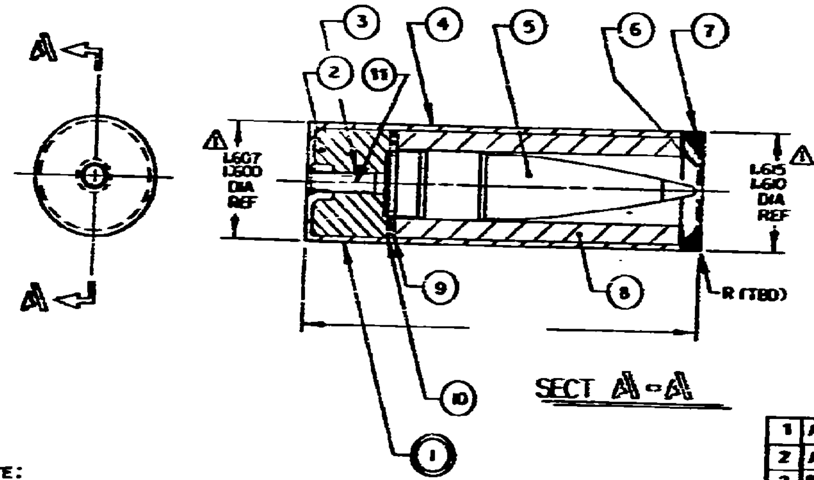
(e) Demonstrate plastic case compatibility to feed, fire and extract from a rapid fire fixture.

(f) Determine the maximum rate of fire that is feasible for the zero draft plastic cartridge.

(g) Re-evaluate DuPont's Glass Reinforced Nylon 6/12 cartridge cases with the improved ignitor interface design.

APPENDIX A

25mm PLASTIC CARTRIDGE ASSEMBLY AND A/AF 25mm ASSEMBLY (GUN) DRAWINGS



NOTE:

MINIMUM TAPER BASED ON MAX TO MIN TOLERANCE.

1	ASSEMBLY
2	AFT CHARGE
3	PRIMER (CALIBER .32 S & W)
4	CASE, COMBUSTIBLE
5	PROJECTILE (PB) (TP)
6	CARTRIDGE CLOSURE
7	FRONT SEAL
8	FORWARD CHARGE
9	NITROCELLULOSE MYLAR® RETAINER
10	RETAINER COVER
11	IGNITOR

Figure A-1. 25mm Plastic Cartridge Assembly

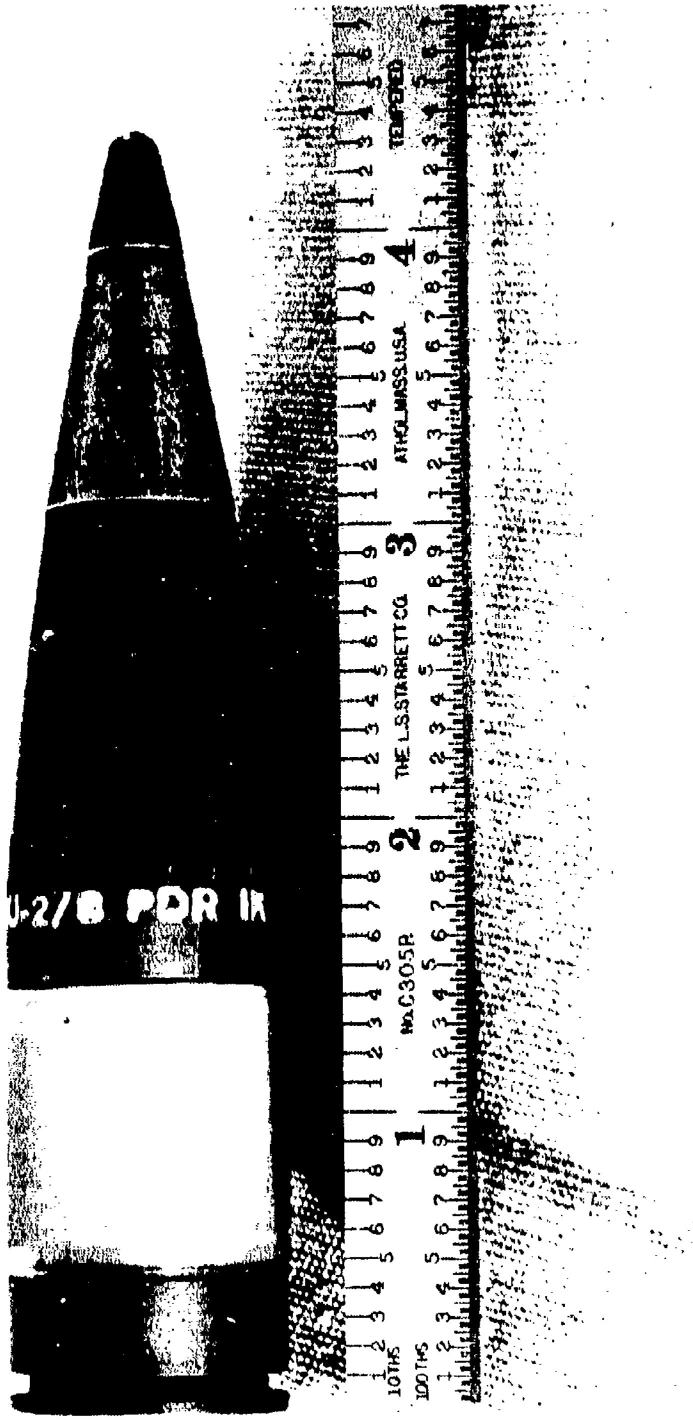
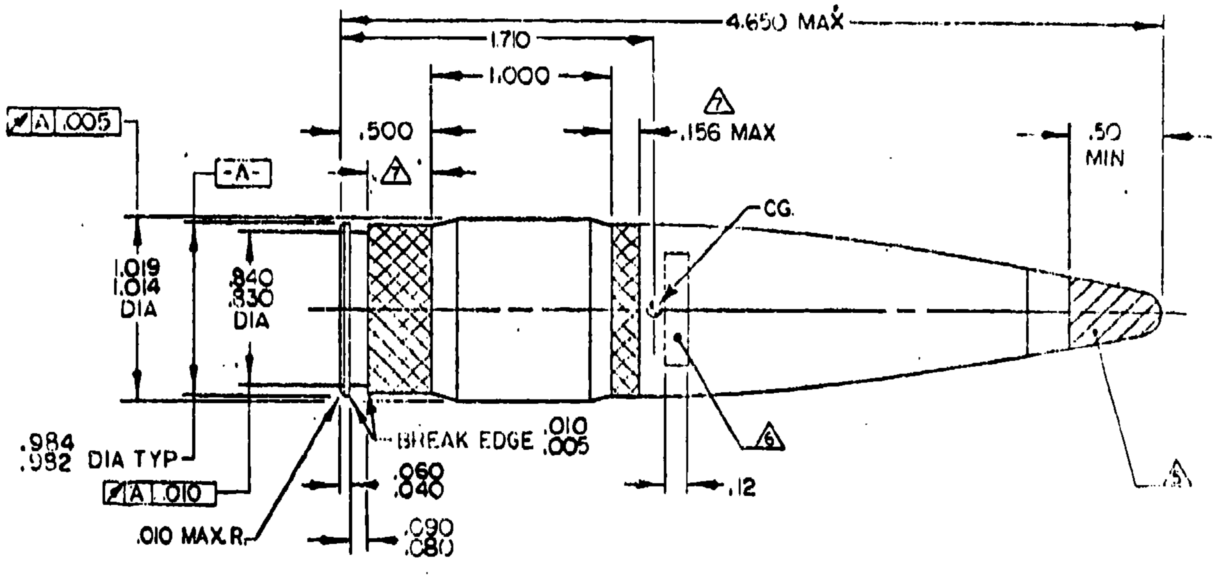


Figure A-2. 25mm GAU-7/A Projectile (3000 Grain, Plastic Band)



NOTES

1 WEIGHT : 3000 ± 50 GRAINS.

2 PROJECTILE INTERIOR AND EXTERIOR SHALL BE FREE OF SOLVENTS, OILS AND OTHER LUBRICANTS.

3 DIMENSION APPLIES AFTER FINISH COATING.

4 DIMENSIONS APPLY AT 70° F ± 10° F

5 LIGHT BLUE COLOR NO. 35109 PER FED STD 595.

6 APPLY DESIGNATION APPROX WHERE SHOWN, COLOR WHITE NO 37875 PER FED STD 595, AS FOLLOWS:

PJU-3/B PDR TP CSY [illegible]

INTERFIX NUMBER

SERIAL NUMBER

YEAR OF MANUFACTURE

7 BONDING ADHESIVE MAY EXTEND .004 MAXIMUM THICKNESS IN AREAS SHOWN.

Figure A-3. Projectile 25mm (TP) Elastic Band

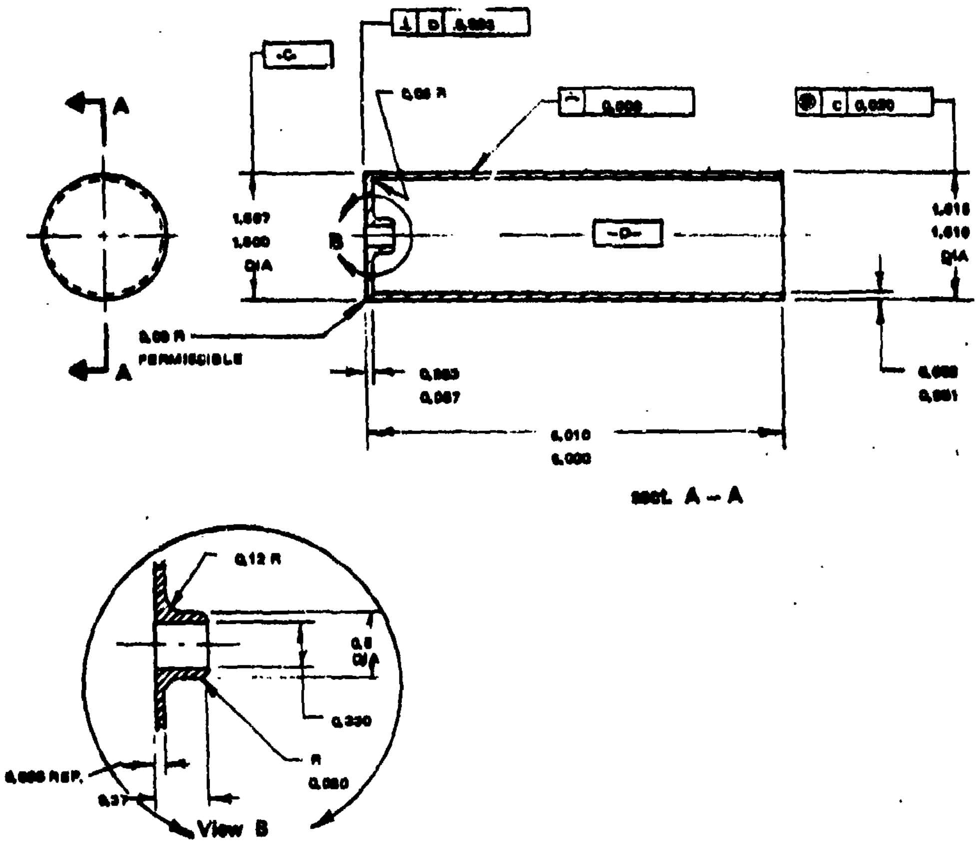


Figure A-4. 25mm Plastic Case

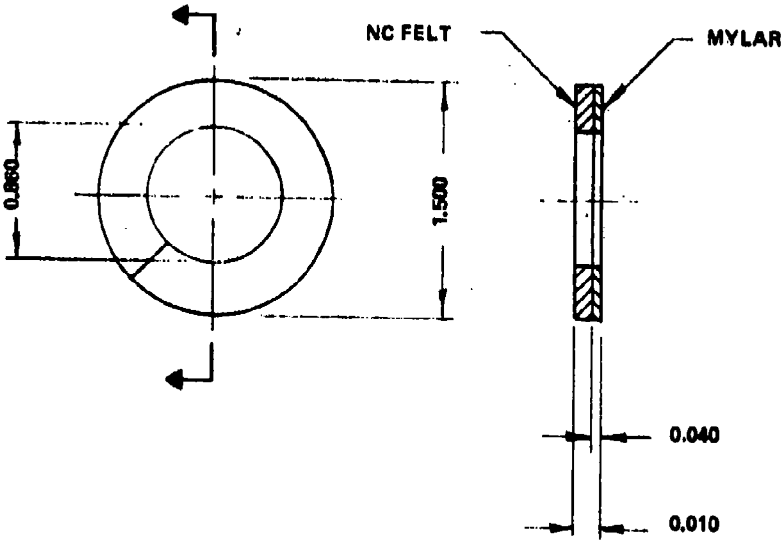
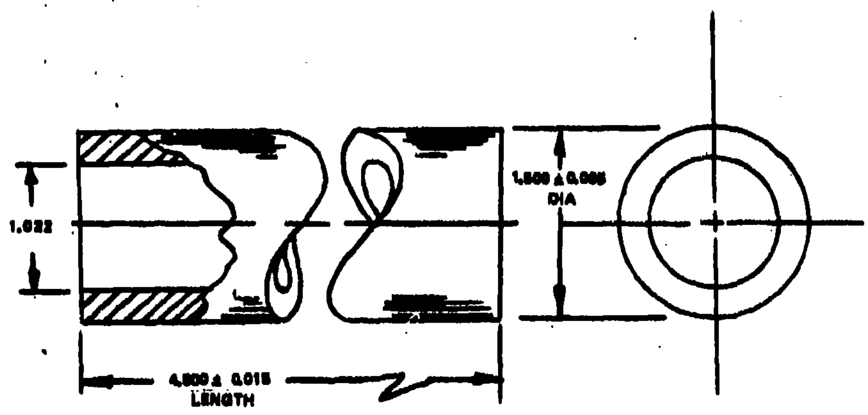
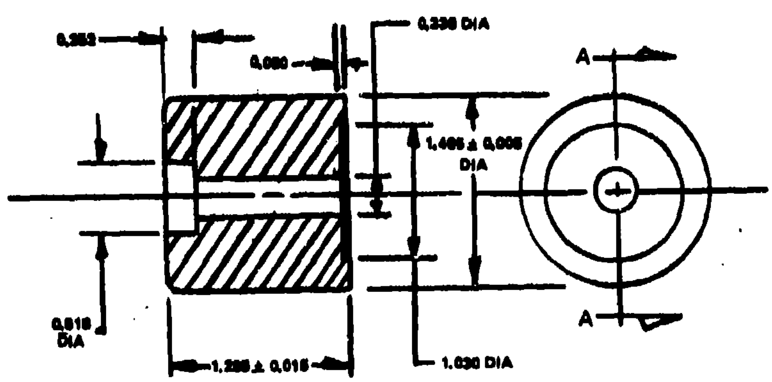


Figure A-5. Projectile Retainer



FORWARD CHARGE



SECTION A-A

AFT CHARGE

Figure A-6. Molded Propellant Charges

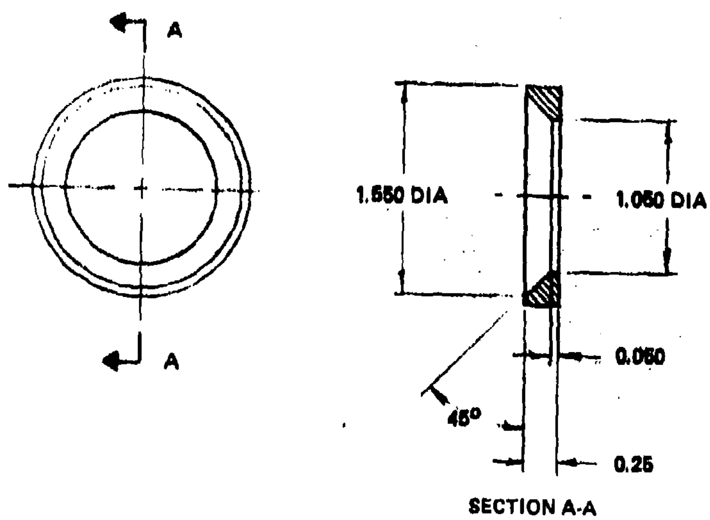


Figure A-7. 25mm Plastic Case Seal, Model A

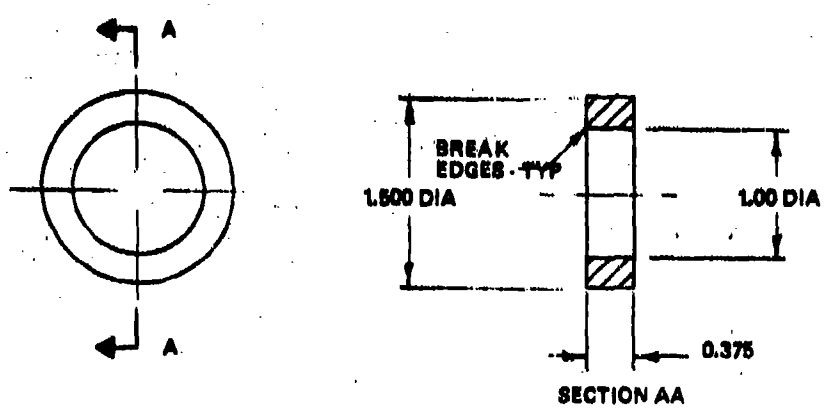
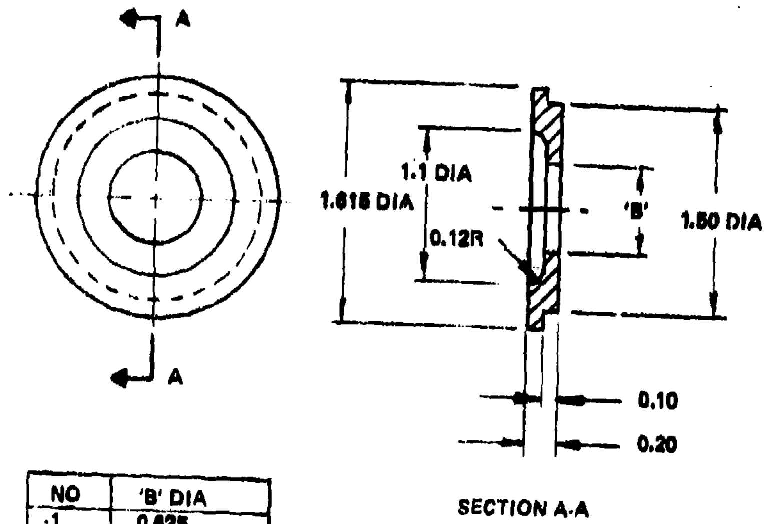


Figure A-8. 25mm Plastic Case Seal, Model B



NO	'B' DIA
-1	0.625
-2	0.750
-3	0.870
-4	0.985
-5	1.100

Figure A-9. 25mm Plastic Case Seal, Model C

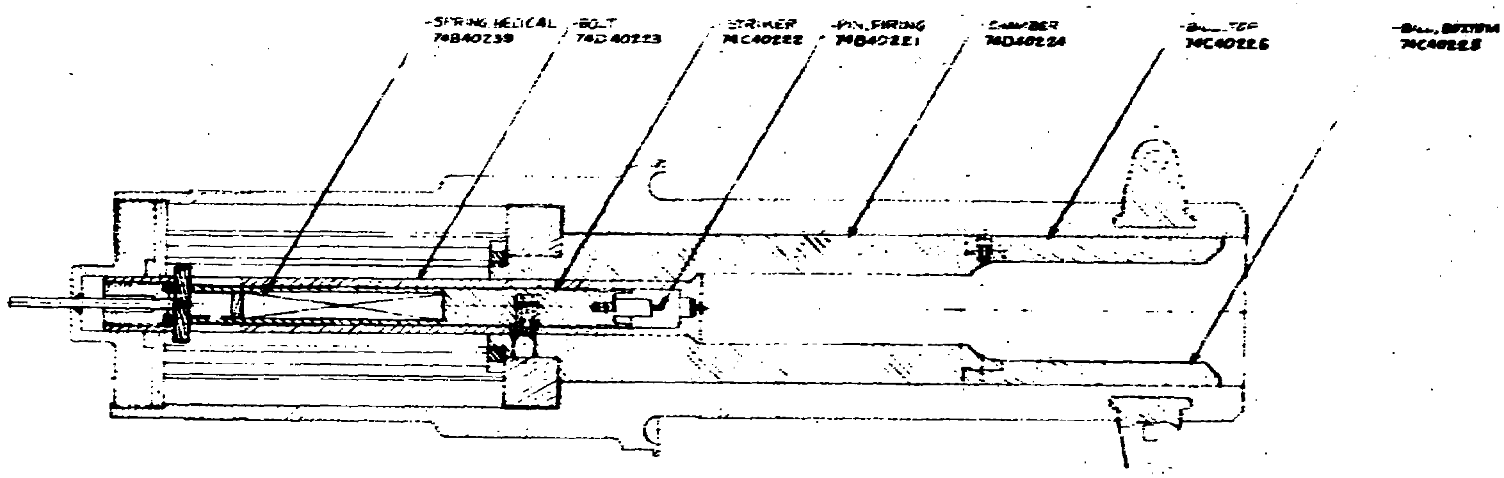


Figure A-10. A/AF 25mm Assembly

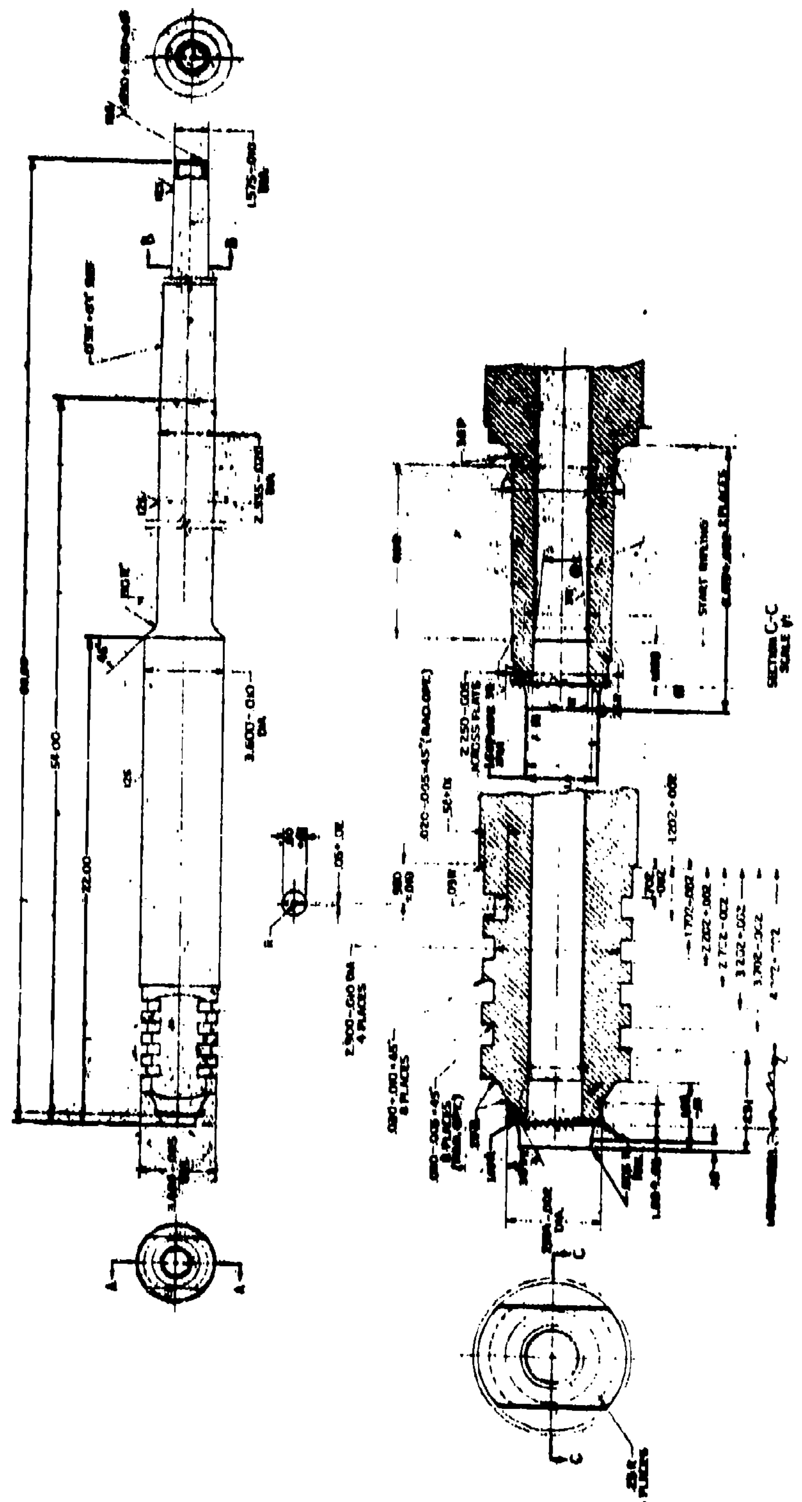


Figure A-11. Barrel, 73F40044MP

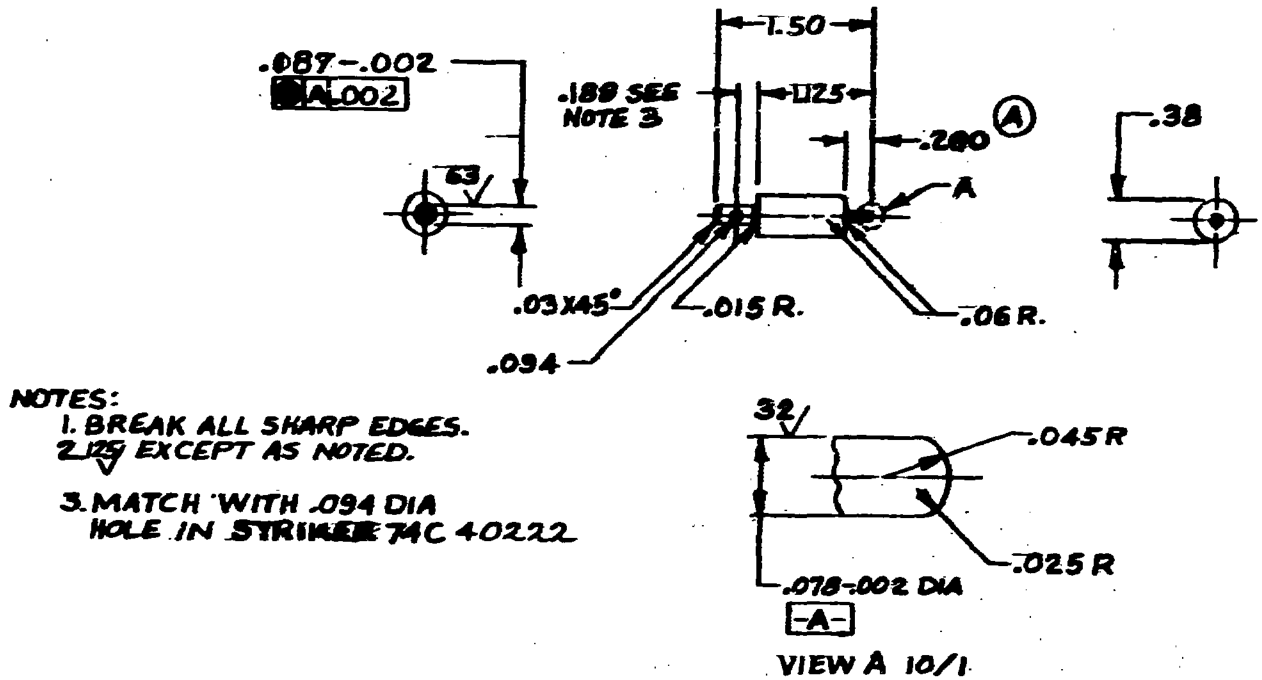


Figure A-12. Pin, Firing, 74B40221

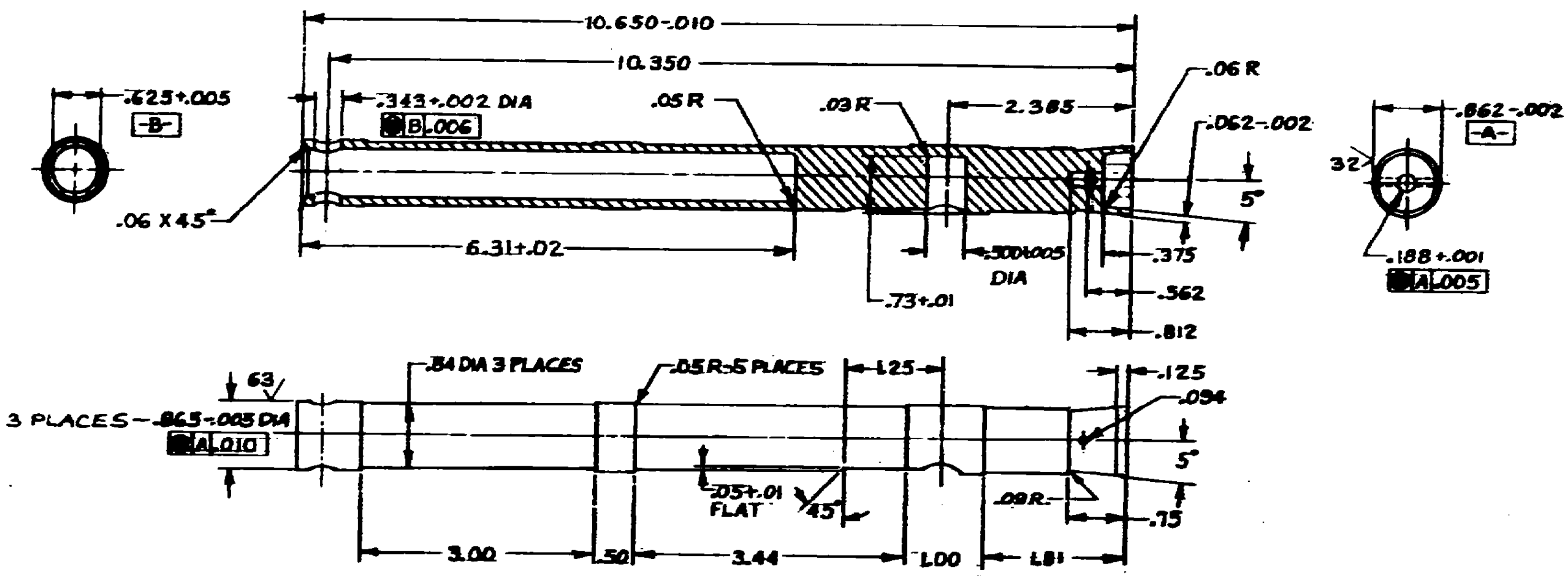


Figure A-13. Striker, 74C40222

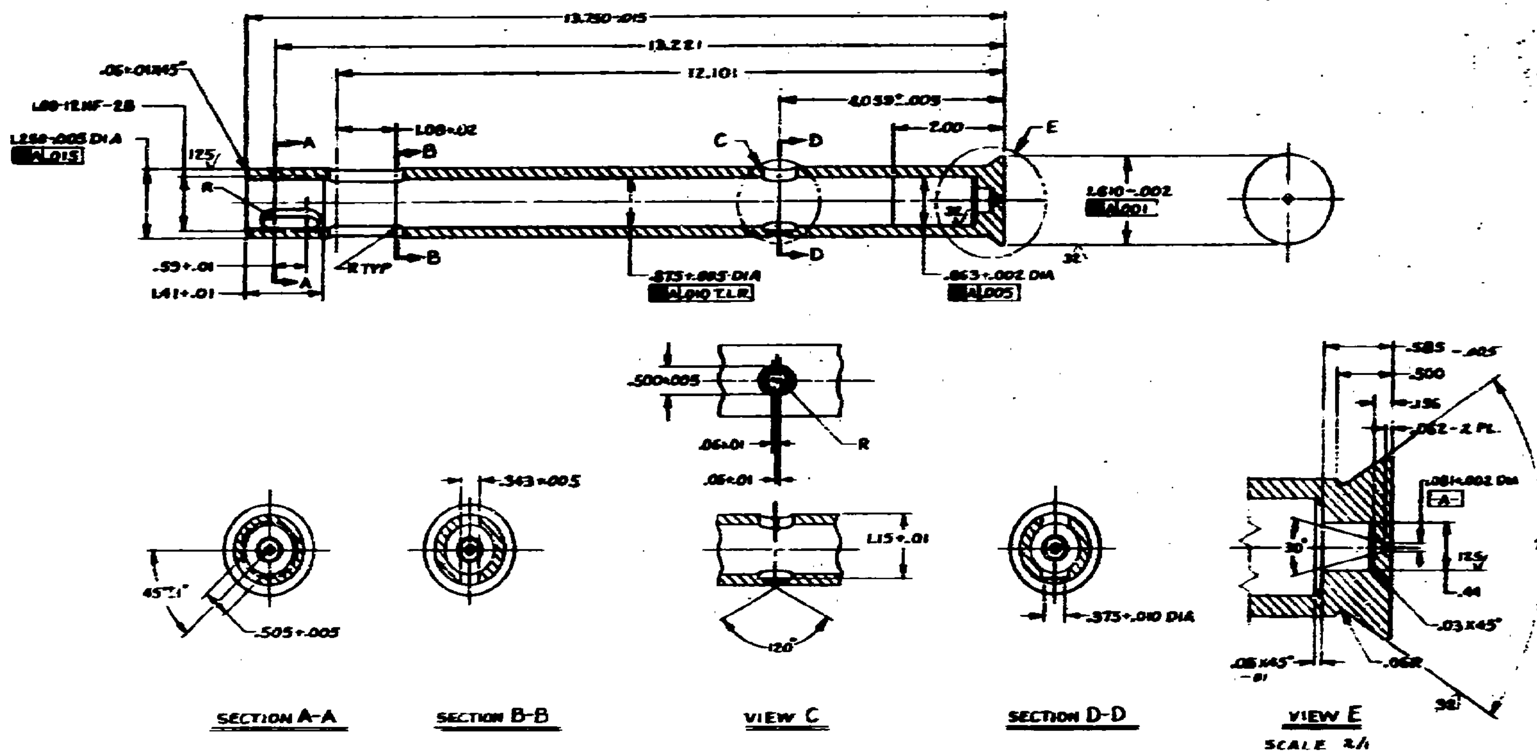


Figure A-14. Bolt, 74D40223

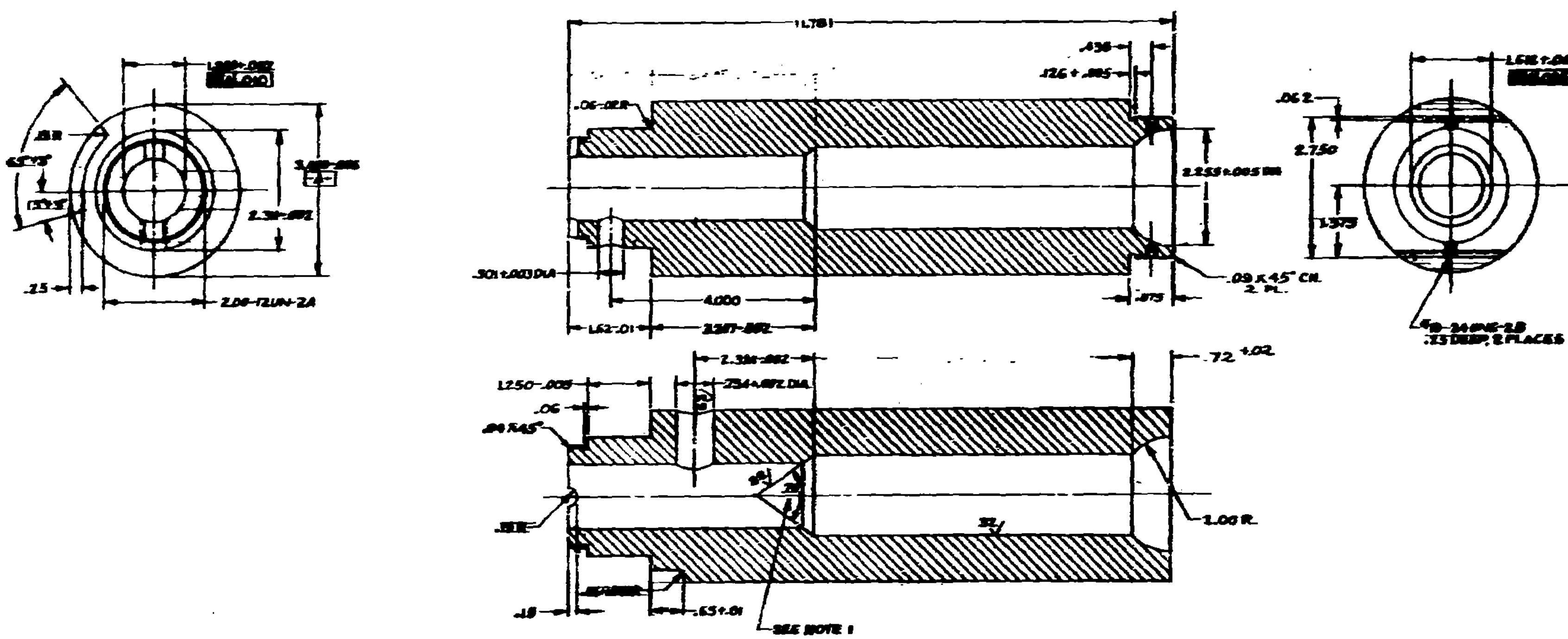


Figure A-15. Chamber, 74D40224

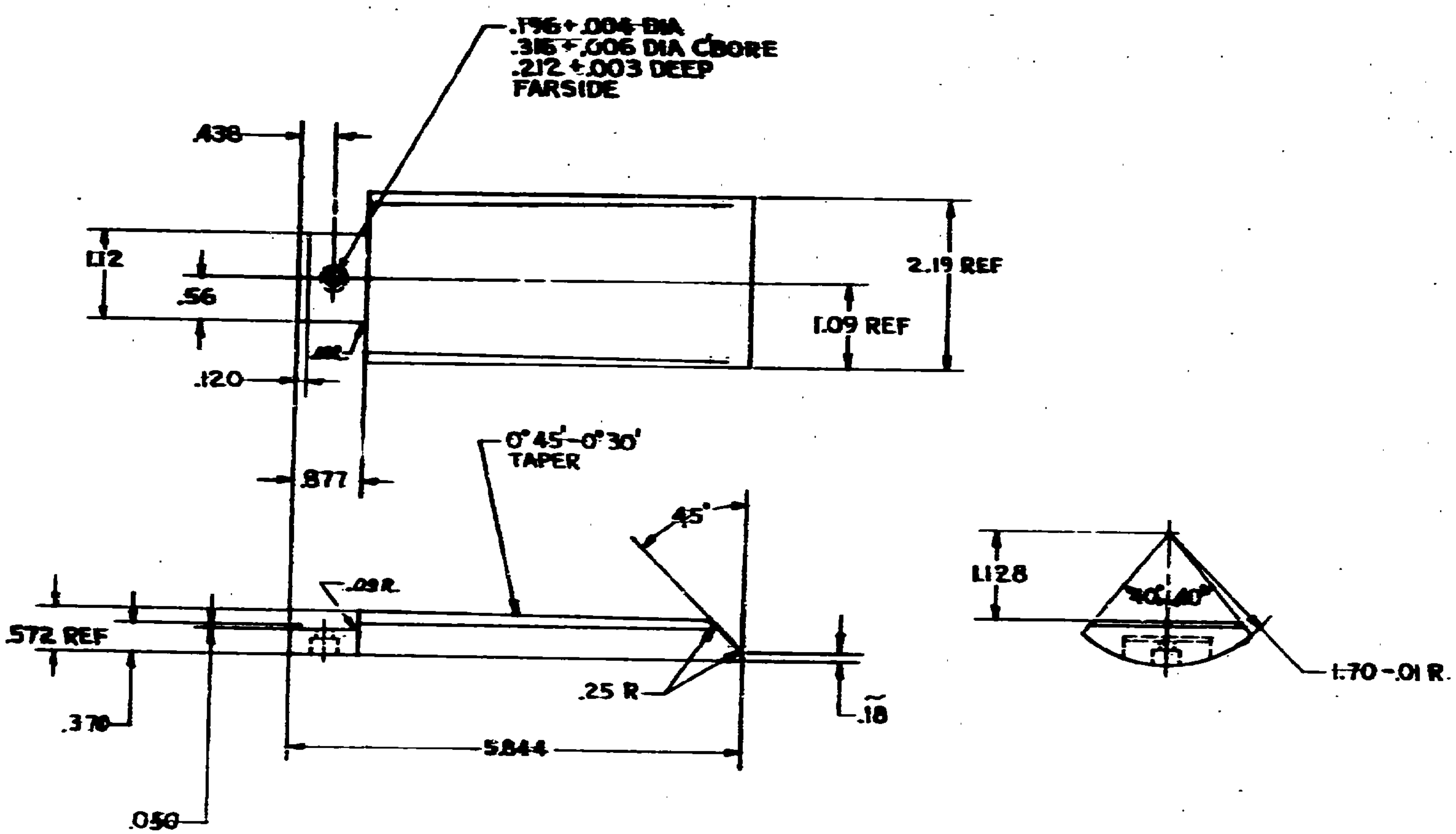


Figure A-16. Bill, Bottom, 74C40225

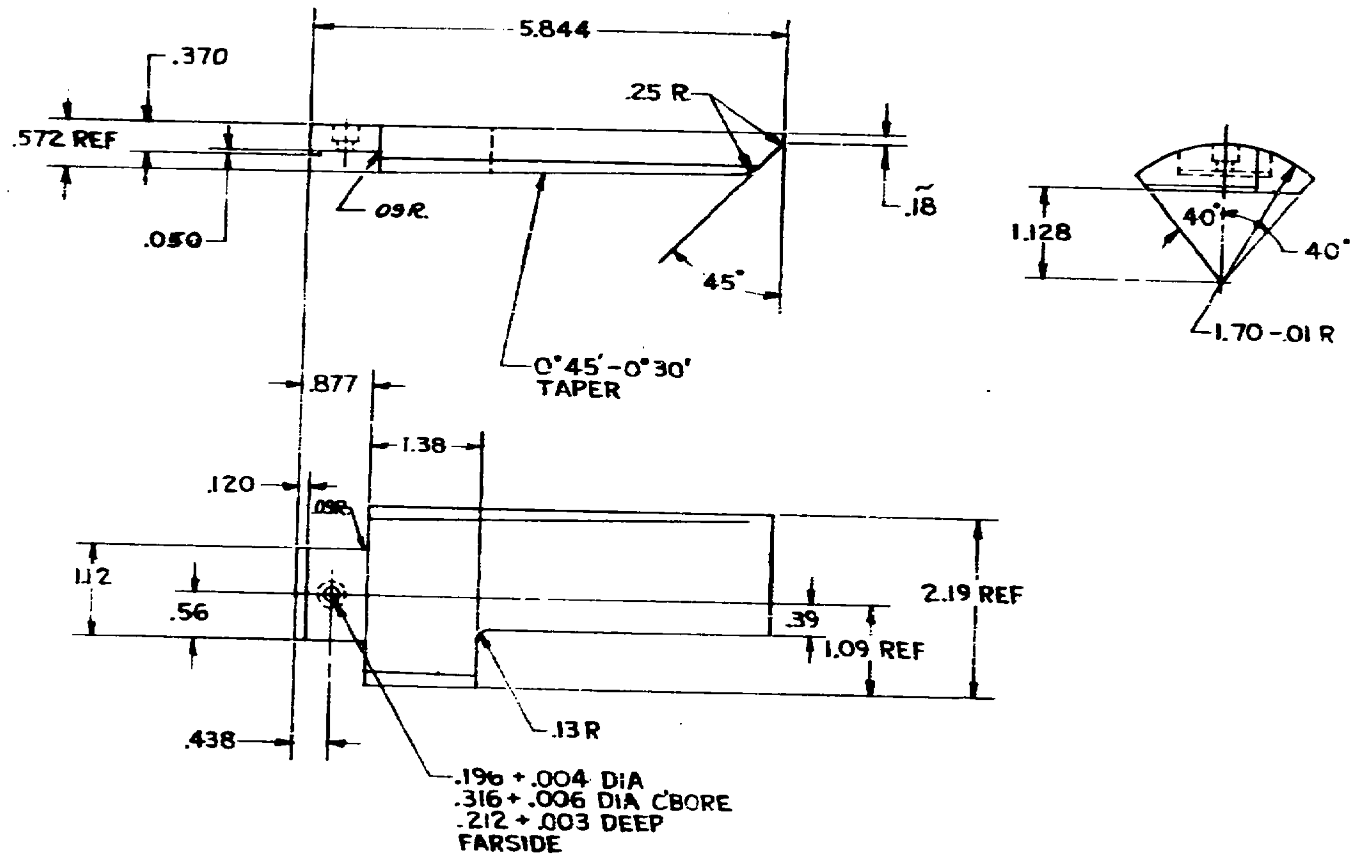


Figure A-17. Bill, Top, 74C40226

NOTES:
1. USE WITH STRIKER 74C40222.
2. COLOR CODE ONE END: YELLOW.
3. MEASURE LOAD AFTER COMPRESSING SPRING TO SOLID HEIGHT 3 TIMES.

[illegible]
MUSIC WIRE [illegible]
HEAT TREAT.

OUTSIDE DIA SOLID, NOT MORE THAN	.598
INSIDE DIA FREE, NOT LESS THAN	.412
ASSEMBLED HEIGHT BASIC	5.47
LOAD AT ASSEMBLED HEIGHT	11 LBS
SOLID HEIGHT, NOT MORE THAN	4.25
DIA OF WIRE (APPROX)	.085
FREE HEIGHT (APPROX)	6.34
NUMBER OF COILS (APPROX)	50
DIRECTION OF COILING	RH
ENDS CLOSED AND GROUND FLAT	
OPERATING HEIGHT BASIC	4.60
LOAD AT OPERATING HEIGHT	22 LBS
SPRING RATE (REF)	12.7 LBS/IN
MANUFACTURE IN ACCORDANCE WITH	

Figure A-18. Spring, Helical, 74B40239

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APPENDIX B

SUPPLIERS

No.	Supplier	Product
1.	Flare Northern 19701 West Goodvale Road Saugus, Calif. 91350	Titanium-barium Nitrate
2.	Teledyne McCormick Selphs 3601 Union Road Hollister, Calif. 95023	Compositions 300432 and 300439
3.	Smith and Wesson 2100 Roosevelt Ave. P. O. Box 2208 Springfield, Mass. 01101	Caliber .32 cartridges
4.	Cascade Cartridge Inc. Lewiston, Idaho 83501	Rifle primers Nos. 400 and 450M
5.	DuPont Company Room 24094 Wilmington, Del. 19898	Zytel® 151, Zytel® 77G43, Hytrel® 4055, Hytrel® 5525, Hytrel® 6435, Nylons 11, 12 and 6/12
6.	Hüls Liquid Nitrogen Processors Birdsboro, Penn.	1938 (38% glass filled nylon)
7.	Brunswick Corporation 4300 Industrial Ave. Lincoln, Nebr. 68504	Epoxy-glass fiber cartridge cases
8.	Borg-Warner Chemicals International Center Parkersburg, W. Va. 26101	Cycopac® and a polyamide-imide
9.	AMOCO Chemicals Corp. 200 E. Randolph Dr. Chicago, Ill. 60601	Torlon® 4203
10.	Celanese Plastics Co. 550 Broad St. Newark, N.J. 07102	Celcon®
11.	3M Company 3M Center St. Paul, Minn. 55101	Aluminized polyethylene terephthalate-polyethylene laminated film (Scotch-Pak® - 20)

APPENDIX B

SUPPLIERS (CONTINUED)

No.	Supplier	Product
12.	Philco-Ford Corporation Ford Road Newport Beach, Calif.	Projectiles
13.	Rilsan Corporation 139 Harristown Road Glen Rock, N.J. 07452	ZM 30 (30% glass filled nylon 11)
14.	Thermofil Inc. 884 Railroad St. Ypsilanti, Mich. 48197	N9-5000 FG (50% glass nylon 12) N9-4000 FG (40% glass nylon 12) N6-4900 FG (49% glass nylon 6/12)
15.	Reichold Chemicals Inc. 525 N. Broadway White Plains, N.Y. 10602	Epotuf® 37-139 adhesive
16.	Irvine Plastics, Inc. 9815 Everest St. Downey, Calif.	Cartridge Cases (Prototype)
17.	DeBell and Richardson Enfield, Conn.	Cartridge Case Mold

APPENDIX C

TEST REPORTS

Test	Title
Serial No. 1	Observe compatibility of Nylon 12, 30 percent glass case with the IITRI gun.
Serial No. 2	Observe the effect of steel support rings on case response to the ballistic cycle.
Serial No. 3	Evaluate Class 3 black powder as an ignitor candidate.
Serial No. 4	Evaluate Class 6 black powder as an ignitor candidate.
Serial No. 5	Evaluate ignitor TMS 300432 and the effect of brass seals on ballistic performance.
Serial No. 6	Evaluate an epoxy/glass filament wound cartridge case.
Serial No. 7	Evaluate Celcon® (Acetal) as a seal material candidate.
Serial No. 8	Observe the effect of the interface seal concept on ballistic performance.
Serial No. 9	Evaluate Zytel® (DuPont Nylon 6/12) as a seal material candidate.
Serial No. 10	Evaluate Torlon® (AMOCO polyamide-imide) as a candidate seal material.
Serial No. 11	Observe the effect of an interface forward seal on ballistic performance.
Serial No. 12	Evaluate the effect of aft charge surface deterrant on ballistic performance.
Serial No. 15	Select a baseline black powder for surface deterred aft charges.
Serial No. 16	Observe the effect of deterred aft charges and different forward charges on ballistic performance.
Serial No. 17	Observe the effect of deterred 5479 aft charges and different forward charges on ballistic performance.
Serial No. 18	Compare the computer data acquisition system to the tape deck/visicorder.
Serial No. 19	Effect of different primers, plain pistol versus small rifle and small rifle magnum.

TEST REPORT

SERIAL NO. 1

OBJECTIVE: To observe the compatibility of the Nylon 12, 30 percent glass case with the IITRI gun.

BACKGROUND: The IITRI single shot test fixture was selected for preliminary evaluation of the zero draft cartridge case. The fixture chamber diameter was 0.003 to 0.005 inch larger than desired and the aft "D" ring seal was badly eroded. The fixture, however, was suitable for preliminary test evaluations. The ignitor material selected was the Teledyne McCormick Selph composition that demonstrated improved performance with GAU-7 over the temperature range.

Five rounds were assembled with:

Forward Charge:	5473 propellant
Aft Charge:	5440 propellant
Retention:	40 mil NC.+ 10 mil mylar
Ignitor:	TMS 432
Primer:	32 S&W
Cases:	Nylon 12, 30 percent glass

BALLISTIC DATA:

WT IGN	P1 MAX	P2 MAX	P3 MAX	VELOCITY	TIME
	ROUND NO--?1				
	42.5	9999	5.03	2906	5.66
0.2	P3 TO LS2 2921				
	LS1 TO LS2 2935				
	ROUND NO--?3				
	47.7	9999	4.82	3183	5.94
0.15	P3 TO LS2 3218				
	LS1 TO LS2 3247				
	ROUND NO--?4				
	44.8	9999	4.54	3041	5.94
0.15	P3 TO LS2 3069				
	LS1 TO LS2 3097				
0.10	ROUND NO--?5				
	51.6	9999	5.96	3562	7.35

DISCUSSION: The ballistic performance indicated overignition and resulted in propellant blowby in all but one test. The No. 5 test had satisfactory performance with only slight blowby. The percentage of blowby increased as the ignitor charge weight increased from 0.1 to 0.2 gram. A round design based that is this sensitive to ignitor weight is not desirable.

The cartridge cases all cracked at the base. The cracks appeared to originate at the ignitor aperture and propagate along the weld lines in the base. The number of weld lines effected varied from one to all three. Each of the cases showed a pin hole in the sidewall approximately 1/4-inch forward of the base. This hole was in line with the erosion path in the aft gun seal. A separation of the case sidewall was observed to originate at the pin hole and propagate forward. The cases were all extracted from the chamber without difficulty. Blind pressure apertures in the chamber showed evidence of plastic flow into recessed areas. Examination of the exterior of the cases showed good evidence of obturation with the chamber. The midchamber pressure aperture and the areas of case failure were surrounded by uncharred nylon.

CONCLUSION: The 432 ignitor indicated over-ignition blowby performance at relatively low charge weights under 0.2 gram. Continued investigation is recommended because of the ballistic insensitivity of the material. The 137 gram propellant charge indicates that the performance goal of 4000 feet per second is possible to attain.

The leaking gun chamber seal was believed to be the cause of the cartridge case failures. A chamber diameter of 1.615 inch is recommended for the universal gun. The incorporation of metal ring seals on each end of the case is recommended as an aid in chamber obturation to prevent case failure.

Satisfactory extraction of the minimum tapered case demonstrated concept feasibility.

25MM PLASTIC CASE
AMMUNITION DEVELOPMENT

S/N: 1
DATE: 26 [illegible] 78
ENGR: [illegible]
AMMO: [illegible]

OBJECTIVE: TO OBSERVE THE COMPATIBILITY OF THE CASE WITH THE IITRI GUN.

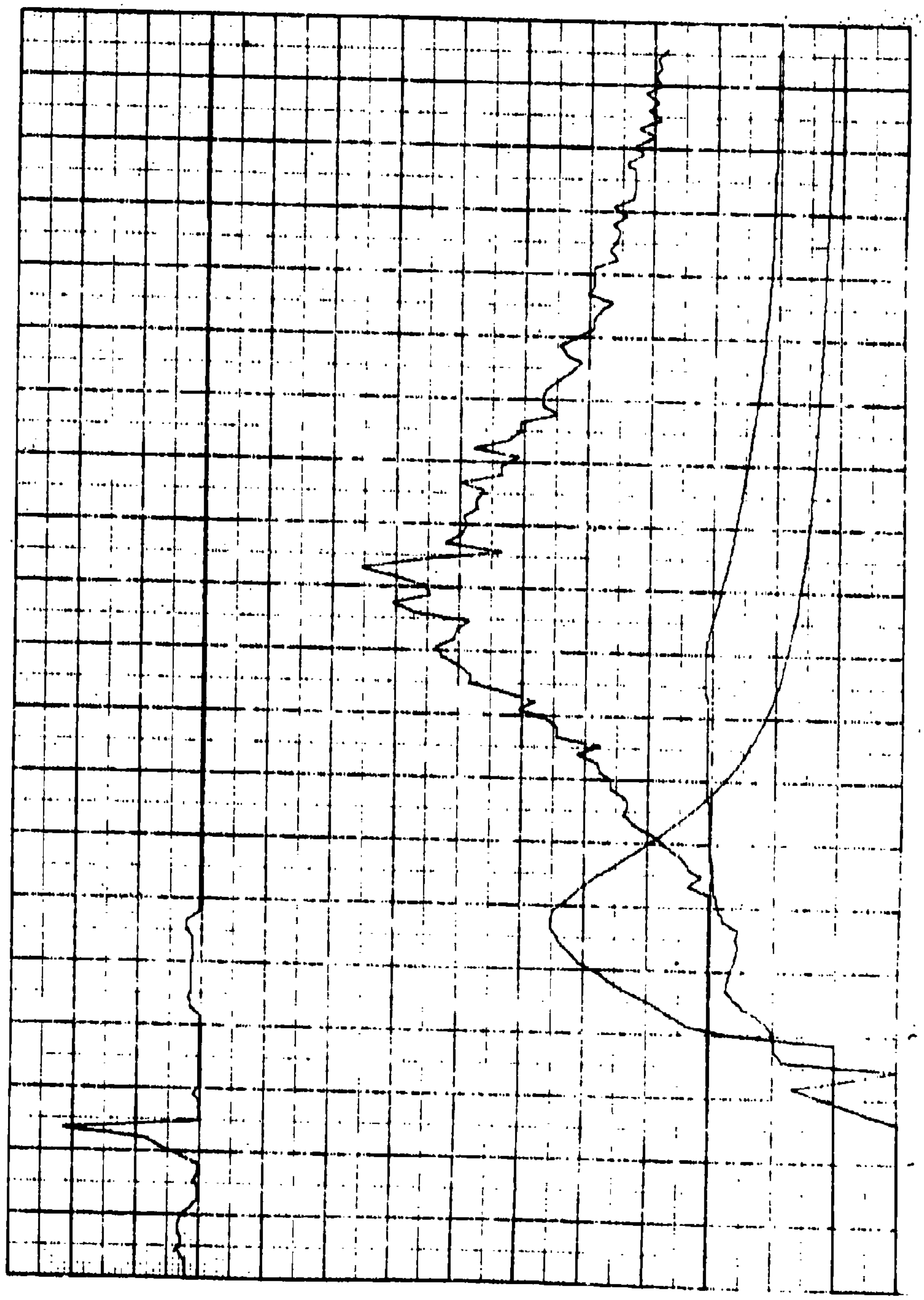
CHAMBER DIA – .005/.003" OVERSIZE

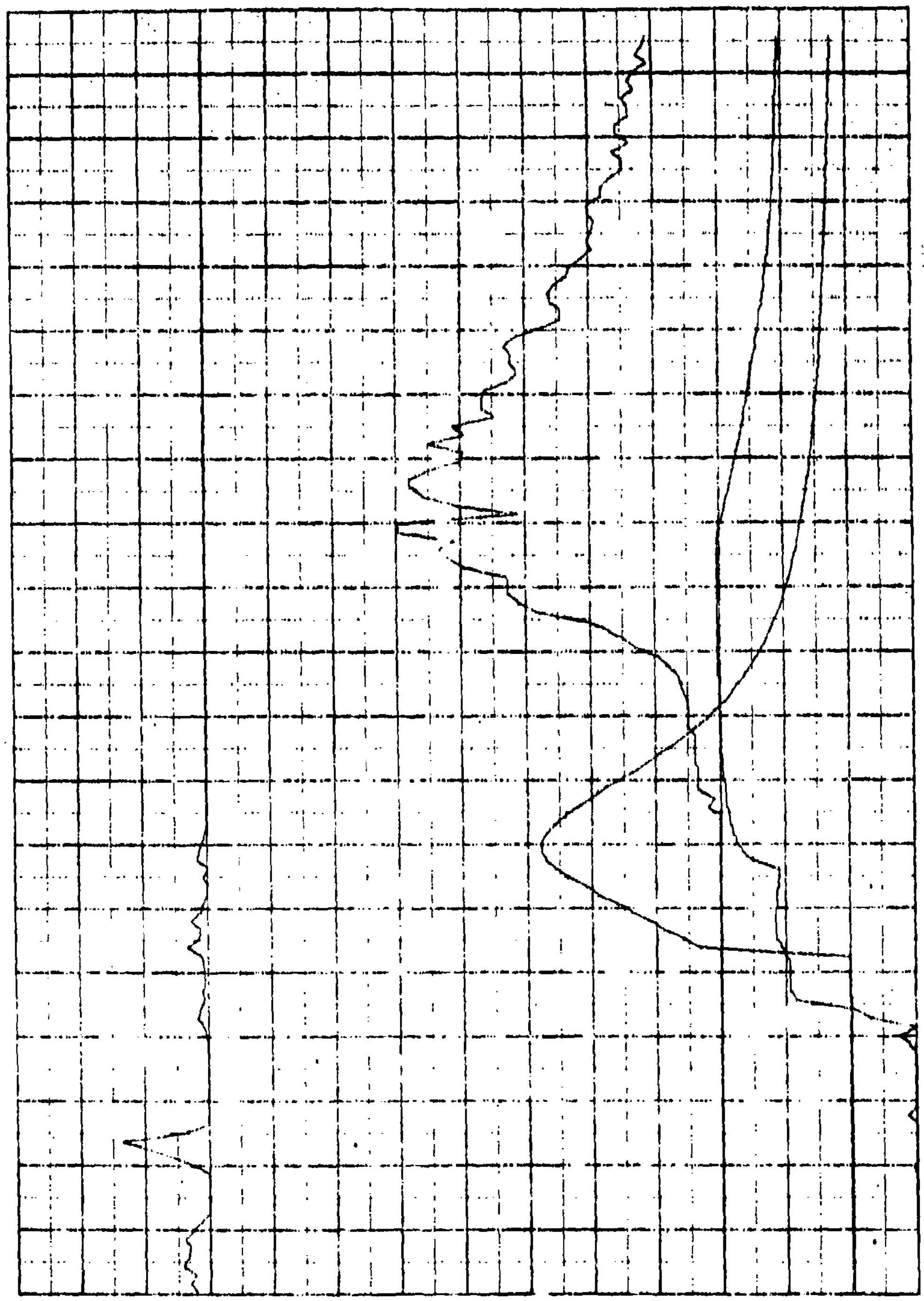
Test Fixture: IITRI, UNIVERSAL, RIA.
Cartridge Case: Dwg. No. SK 300460, Rev. ____, Mat'l NYLON 12, 30% GLASS
Dwg. No. ________, Rev. ____, Mat'l ________.
Projectile: Dwg. No. 300347, Rev. A, Plastic Band, 3000 Grain.
Primer: Type PISTOL, Lot No. ________, No. ________.
Flash Tube: 3256W, 38 Special, ________.
Projectile Retention: 40 Mil NC, 10 Mil Mylar, ____ Mil
Ignitor: THS 300432, Seals: IN GUN - AFT SEAL ERODED
Propellant: Fwd Charge 5493, Lot No. 53-415.
Aft Charge 5440, Lot No. 50-418.
Insert NA, Lot No. ________.

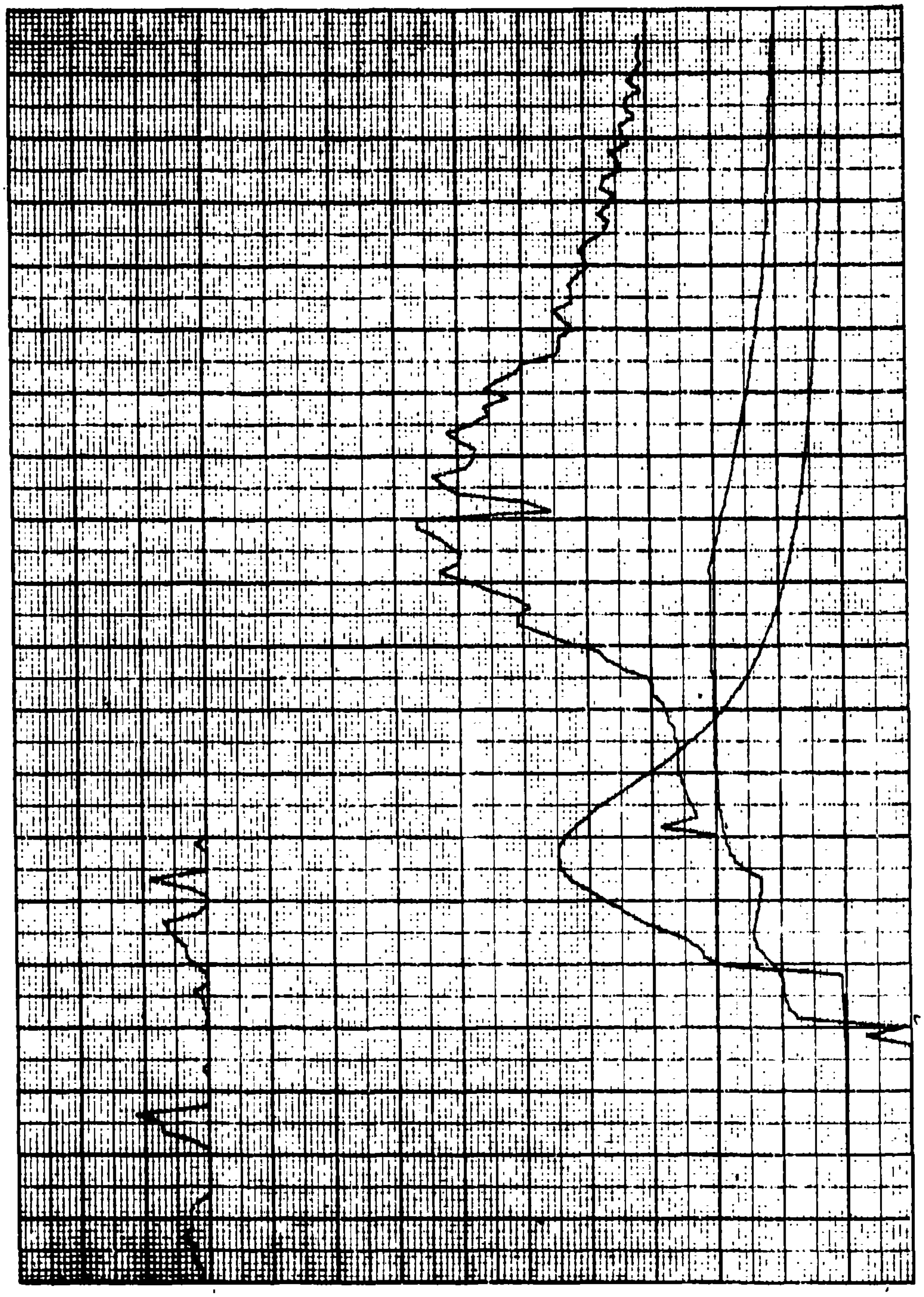
REMARKS:

ROUND NO.	PROPELLANT WT (GRAMS)			TOTAL PROP. WT	IGNITOR WT
	FWD	AFT	INSERT	(GRAMS)	(GRAMS)
1	98.90	37.36	—	136.16	0.2
2	99.72	37.38	—	137.10	0.1
3	99.38	37.28	—	136.60	0.15
4	100.05	37.33	—	137.38	0.15
5	100.05	37.24	—	137.29	0.1

FORM NO. SG-555-81







SAMPLES FOR LABORATORY EVALUATION

Project or Charge No. 23103 Date 4-25-74

Material Description:

① 1-fwd grain Lot 5473
② 1-aft grain Lot 8446-9
③ 1-aft grain Lot 5440

Lot No. see above Batch No. —

Vendor R&D Date Identification

Tests Required:

M & V analyses

(Rodney Samples)

Submitted By Eaton
Report Data To Eaton & Carey

Analytical Results:

	H_2O	ACE	ETHER	M&V
Fwd 5473	.49	.17	.37	1.03
AFT 8446-9	.36	—	.10	.46
AFT 5440	.36	—	.28	.64

Analyst Young Approved
Date 4-29-74

QCF-06-01

DATA EVALUATION COPY

TEST REPORT

SERIAL NO. 2

OBJECTIVE: To observe the effect of steel support rings on case response to the ballistic cycle.

REFERENCE: S/N 1

BACKGROUND: The test results from series No. 1 indicated that the space between the case and the chamber was sufficient to cause the case to crack. The space was estimated to be 0.015 inch. The incorporation of steel support rings at each end of the case was made to strengthen the case in these areas.

Five rounds were assembled with:

Forward Charge:	5473 propellant
Aft Charge:	8446-9 propellant
Ignitor:	432, 439, TBN
Retention:	40/10 - NC/mylar
Primer	32 S&W
Case:	Nylon 12, 30 percent glass with support rings at each end.

BALLISTIC DATA: Ballistic data was not obtained on four tests because of computer difficulties and an action time longer than 50 milliseconds. One test with 0.45 gram of ignitor 432 is shown below:

```
P1 MAX       P2 MAX      P3 MAX      VELOCITY     TIME
-------------------------------------------------------
ROUND NO-- 9
  -4.8       ' 22.1        3.86        2880      5.46
 3.42
   0           32.52       0
LS1 TO LS2 2856
P3 TO LS2 2863
```

DISCUSSION: The titanium barium nitrate (TBN) ignitor produced the long action time. The TBN was a suitable ignitor in the GAU-7 program but was identified to be low in gas evolution. Examination of the spent case revealed that the brass S&W ignitor tube was melted. This behavior indicates that the TBN ignited but that it did not communicate to the base propellant effectively. The audible output and the muzzle flash of the round containing ignitor 439 was satisfactory and would be associated with acceptable performance. The round with ignitor 432 produced b[illegible]by performance as recorded and observed with the muzzle flash.

The cartridge cases were removed from the chamber easily but in two pieces. The cases each failed at the circumferential intersection of the steel ring and the case sidewall. The case bases remained intact and the case sidewalls did not crack longitudinally. The exterior surface of each case showed the exposure to combustion gases and there was no evidence of obturation. This indicates that the cases failed very early in the ballistic cycle. The strength of the steel rings did provide the support in the base but not in the sidewall.

CONCLUSION: The IITRI test fixture chamber diameter of 1.618 to 1.620 inch was greater than could be tolerated with the 1.607 to 1.600 inch diameter cartridge case without suitable reinforcement at the case base. It is recommended that additional testing be conducted in a 1.615 $\pm$ 0.001 inch diameter (GAU-7) chamber.

Ignitor 439 should be reevaluated. Ignitor TBN should be abandoned.

25MM PLASTIC CASE
AMMUNITION DEVELOPMENT

S/N: 2
DATE: 10 MAY
ENGR: CARY
AMMO: CARY

OBJECTIVE: TO OBSERVE THE EFFECT OF STEEL SUPPORT RINGS AT EACH END OF THE CASE

CHAMBER DIA 1.618" 1.620"

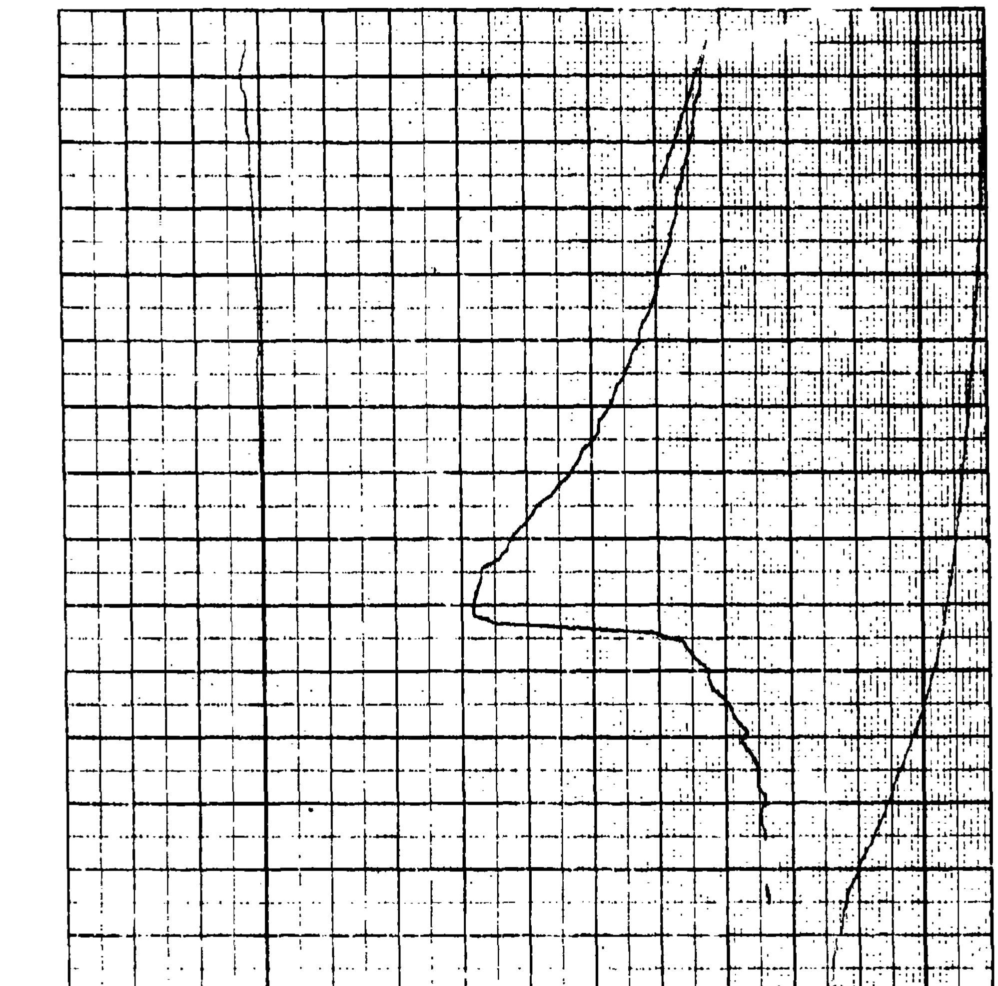
Test Fixture: TTTB, UNIVERSAL, RIA.
Cartridge Case: Dwg. No. SK 300460 Rev.____, Mat'l NYLON 12, 30% GLASS
Dwg. No. ______, Rev.____, Mat'l ______.
Projectile: Dwg. No. 300347, Rev. A, Plastic Band, 3000 Grain.
Primer: Type ASTOL, Lot No.______, No.______.
Flash Tube: 32540, 38 Special, ______.
Projectile Retention: 40 Mil NC, 10 Mil Mylar, ____ Mil
Ignitor: 432, 439, TBN FINES, Seals: IN GUN - AFT BONDED
Propellant: Fwd Charge 5873, Lot No. 53-501
Aft Charge 8416-9, Lot No. 89-503
Insert N/A, Lot No.______.

RINGS

REMARKS: STEEL SUPPORT RINGS 0.030" THICK

ROUND NO.	PROPELLANT WT (GRAMS) FWD	AFT	INSERT	TOTAL PROP. WT (GRAMS)	IGNITOR WT (GRAMS)
					TMS 432
6	99.87	36.89	—	136.76	0.1
7	100.77	36.81	—	136.88	0.15
9	99.46	36.80	—	136.26	0.45
					TBN FINES
8	99.78	36.88	—	136.66	0.75
					TMS 439
10	99.58	37.05	—	136.63	0.34

FORM NO. SG-555-81



TEST REPORT

SERIAL NO. 3

OBJECTIVE: To evaluate Class 3 black powder as an ignitor candidate.

BACKGROUND: It is necessary to establish a baseline round configuration early in a program so that performance improvements can be measured. Black powder is usually selected as a baseline ignitor because of its ballistic properties and reproducibility. Class 3 black powder was selected for this test because it was used satisfactorily in the GAU-7 program.

Fifteen rounds were assembled with:

Forward Charge:	5473 propellant (11 rounds), 5479 (4 rounds)
Aft Charge:	8446-9 propellant
Ignitor:	Black Powder, Class 3
Retention:	40/10 - NC/mylar
Primer:	32 S&W
Case:	Nylon 12, 30 percen glass
Test Fixture:	Universal

BALLISTIC DATA: The ballistic data are listed separately because of the large percentage of individual tests.

DISCUSSION: The black powder charge weight was varied from a high of 1.4 grams to a low of 0.5 gram. The performance ranged from over-ignition blowby (1.4 gram) to under-ignition blowby long action time (0.50 gram). The erratic performance indicated that class 3 black powder was not a suitable ignitor candidate. The under-ignition performance was typical of a low gas producing ignitor. The outer case in the GAU-7 round supplemented the black powder gas generation rate to produce the desired mass for a balanced shot start cycle.

One round (No. 21) was tested with a 0.1 inch thick brass spacer in the forward end to provide an additional 0.050 inch crush up. The center hole diameter was 1.025 inch. This round provided the best ballistic performance of the series with 0.5 gram of the class 3 ignitor. Examination of the spacer after the test showed that the spacer was deformed and the projectile would not pass through the center. The interference fit with the projectile occurred during the ballistic cycle. It is possible that slowing the projectile velocity prior to engraving could provide the desired delay or hesitation necessary for stable propellant ignition.

Four additional rounds were evaluated with nylon seals similar in dimension to the brass spacer. One round repeated the results of improved performance. The nylon spacer was recovered almost intact. The three other spacers were almost consumed, leaving a narrow rim on the forward case lip.

The most significant factor of this test was the case behavior. None of the cases cracked and all were easily extracted from the gun chamber. The 0.050 inch crush up did not appear to be detrimental to case performance. All the cases appeared to obturate with the chamber at the case base. Gas flow to the outside of the case occurred at the forward end. Two cases had longitudinal creases originating at the forward end that were evidently formed by venting gas trapped between the case and chamber. The absence of the chamber pressure aperture improved the case to chamber obturation.

CONCLUSION: The forward seal appears to influence the ballistic performance by slowing down the projectile motion in the shot start cycle. Additional study in this area is recommended.

The cartridge case is compatible to the GAU-7 gun chamber and can be extracted without difficulty.

```
P1 MAX      P2 MAX      P3 MAX      VELOCITY    TIME
----------------------------------------------------
ROUND NO 11
   30.2      -1          4.01        2565      5.94
-62.316
   29.95      0          4.62
LS1 TO LS2 2580
P3 TO LS2 2572
ROUND NO 12
   0          44.6       6.86        3816      21.25
   0          69.15      0
LS1 TO LS2 3852
P3 TO LS2 3833
```

```
OPTION FOR F2   1=RR   2=F2MAX?2
DISTANCE TO FIRST LIGHT SCREEN?23
DISTANCE BETWEEN LIGHT SCREENS?2
N-RAD   1=YES  2=NO?2

P1 MAX     P2 MAX     P3 MAX    VELOCITY    TIME     K.E.   P.E.
------------------------------------------------------------------
ROUND NO 15
   30.4      -.7        2.68       2648      5.8     .011   .262
   31.34     0          2.2
LS1 TO LS2 2644
P3 TO LS2 2646
ROUND NO 16
   33.6      .2         2.75       2545      5.94    .01    .218
   44.81     0          4.34
LS1 TO LS2 2559
P3 TO LS2 2552
ROUND NO 17
   34.3      .3         2.43       2526      5.67    .01    .211
   47.15     0          4.35
LS1 TO LS2 2559
P3 TO LS2 2542
ROUND NO 18
   23.1      .1         2.49       2312      8.27    9.00000E-03
 .262
   48.94     0          4.16
LS1 TO LS2 2302
P3 TO LS2 2307
ROUND NO 19
   29.4      .4         3.67       2830      7.04    .013   .309
   48.26     0          2.57
LS1 TO LS2 2806
P3 TO LS2 2818
ROUND NO 20
   37.6      .7         3.73       2830      11.43   .013   .241
   44.54     0          3.46
LS1 TO LS2 2856
P3 TO LS2 2843
ROUND NO 21
   51        1.3        4.5        3646      6.63    .021   .295 Brass Spacer
   47.24     0          1.1                                      0.1 x 1.025 Inch ID
LS1 TO LS2 3716
P3 TO LS2 3681
ROUND NO 22
   32        .6         3.18       2855      8.82    .013   .288 Nylon Seal
   46.42     0          2.37
LS1 TO LS2 2881
P3 TO LS2 2868
ROUND NO 23
   32.6      .6         5.69       3491      6.49    .019   .424 Nylon Seal
   47.19     0          .2
LS1 TO LS2 3476
P3 TO LS2 3484
ROUND NO 24
   29.6      .6         2.9        2606      8.34    .011   .259 Nylon Seal
   45.62     0          3.57
LS1 TO LS2 2661
P3 TO LS2 2603
ROUND NO 25
   33.2      .6         8.04       3646      24.07   .021   .454 Nylon Seal
   61.43     0          0
LS1 TO LS2 3592
P3 TO LS2 3620
```

25MM PLASTIC CASE
AMMUNITION DEVELOPMENT

S/N: 3
DATE: 14 JUN 78
ENGR: CARY
AMMO: SAXON

OBJECTIVE: TO EVALUATE CLASS 3 BLACK POWDER AS A BASELINE IGNITOR CANDIDATE

Test Fixture: IITRI, ~~UNIVERSAL~~, RIA.
Cartridge Case: Dwg. No. ~~SK 100458~~, Rev.____, Mat'l NYLON 12, 30% GLASS
Dwg. No. ________, Rev.____, Mat'l________.
Projectile: Dwg. No. 300347, Rev. A, Plastic Band, 3000 Grain.
Primer: Type PISTOL, Lot No.________, No.________.
Flash Tube: 25SW, 38 Special, ________.
Projectile Retention: 40 Mil NC, 10 Mil Mylar, I8150 BONDED
Ignitor: B P (3)
Seals: NONE, BRASS, NYLON
Propellant: Fwd Charge 5473, Lot No. 59-66.
Aft Charge 8446-9, Lot No. 89-63.
insert —, Lot No. —.

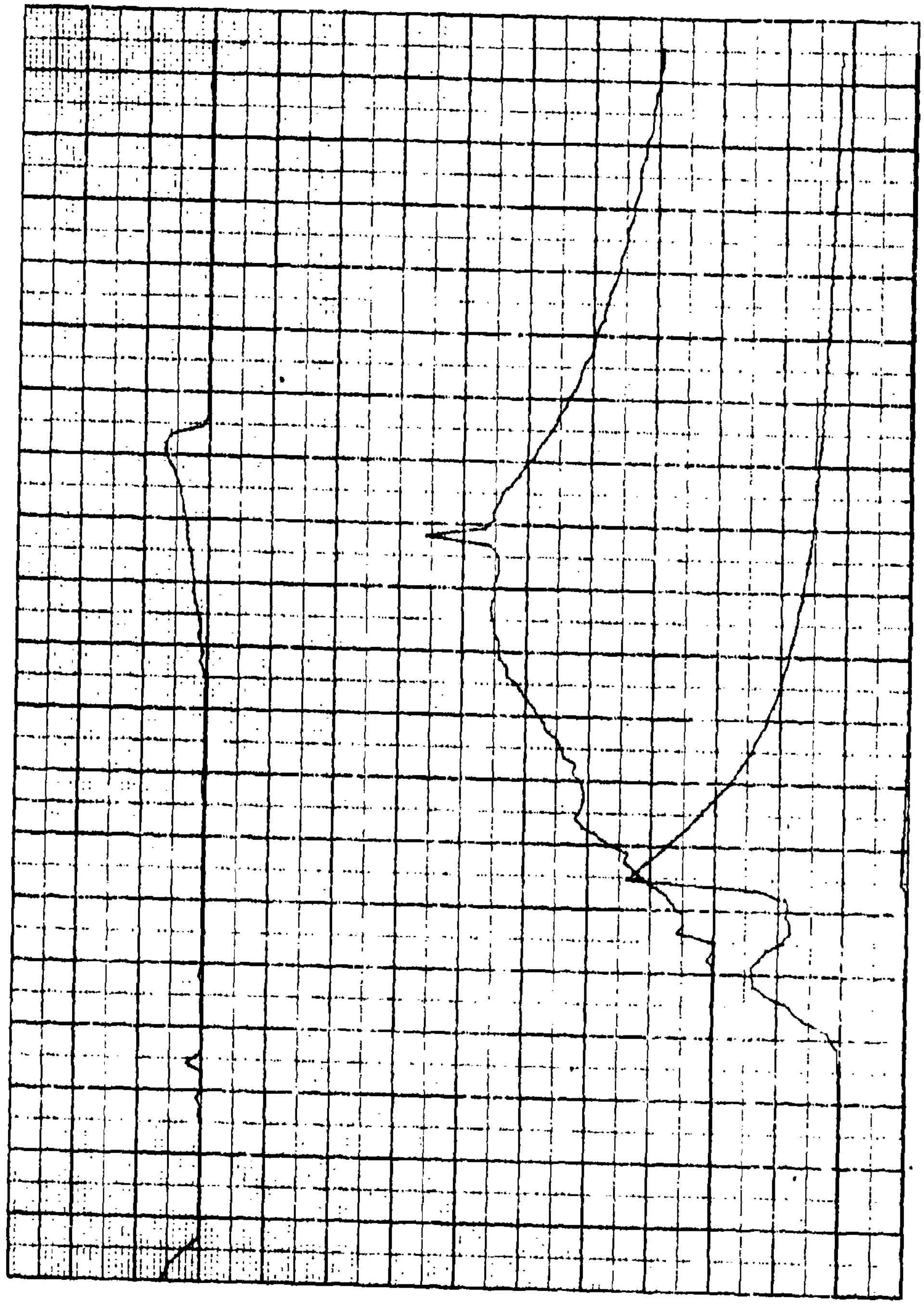
REMARKS: RD. LENGTH 6.050" PLUS 0.050" & 0.100" THICK SPACER FOR CRUSH UP. NYLON SEAL (SK300520) 6.050" RD. LENGTH.

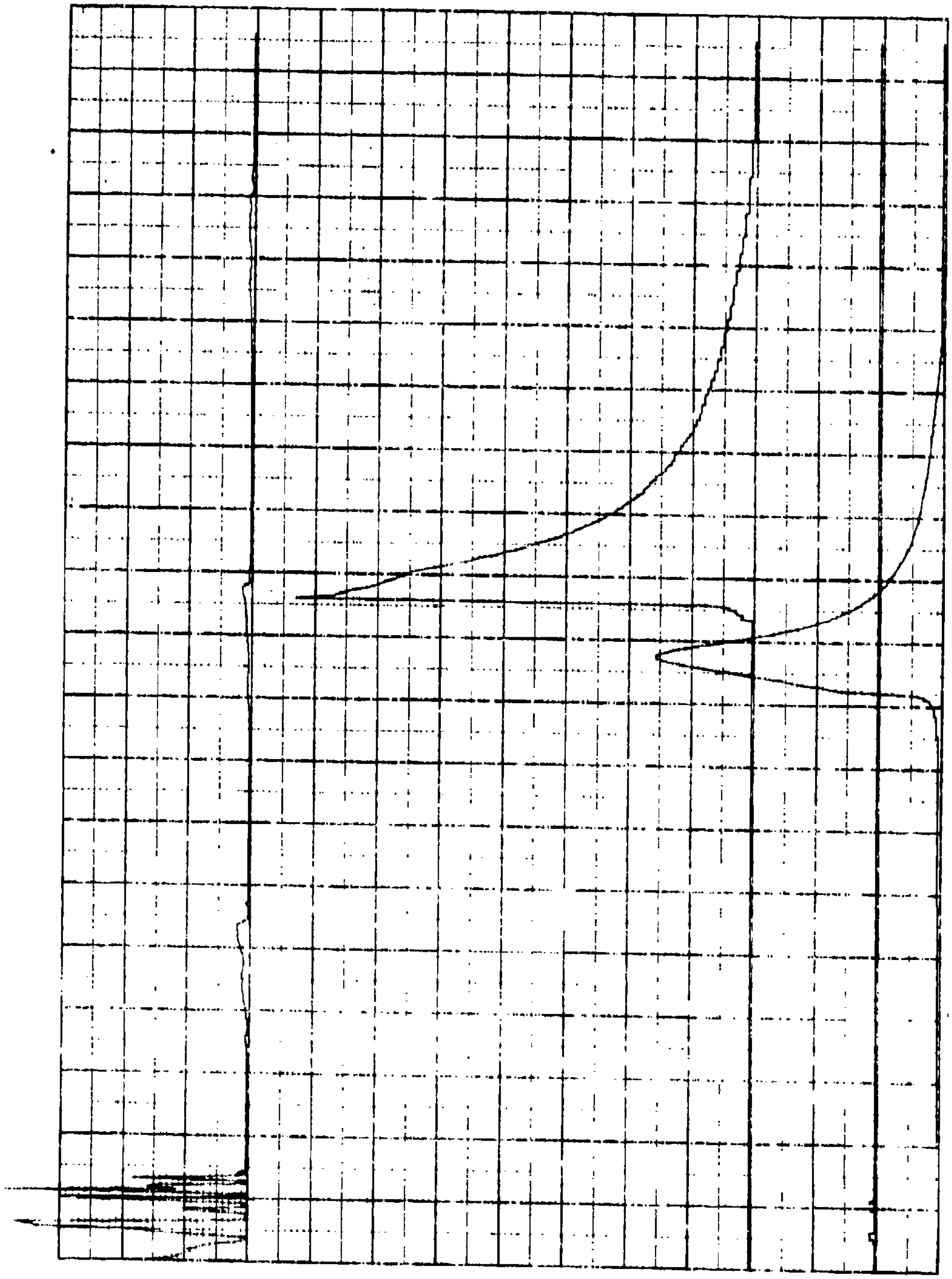
: :

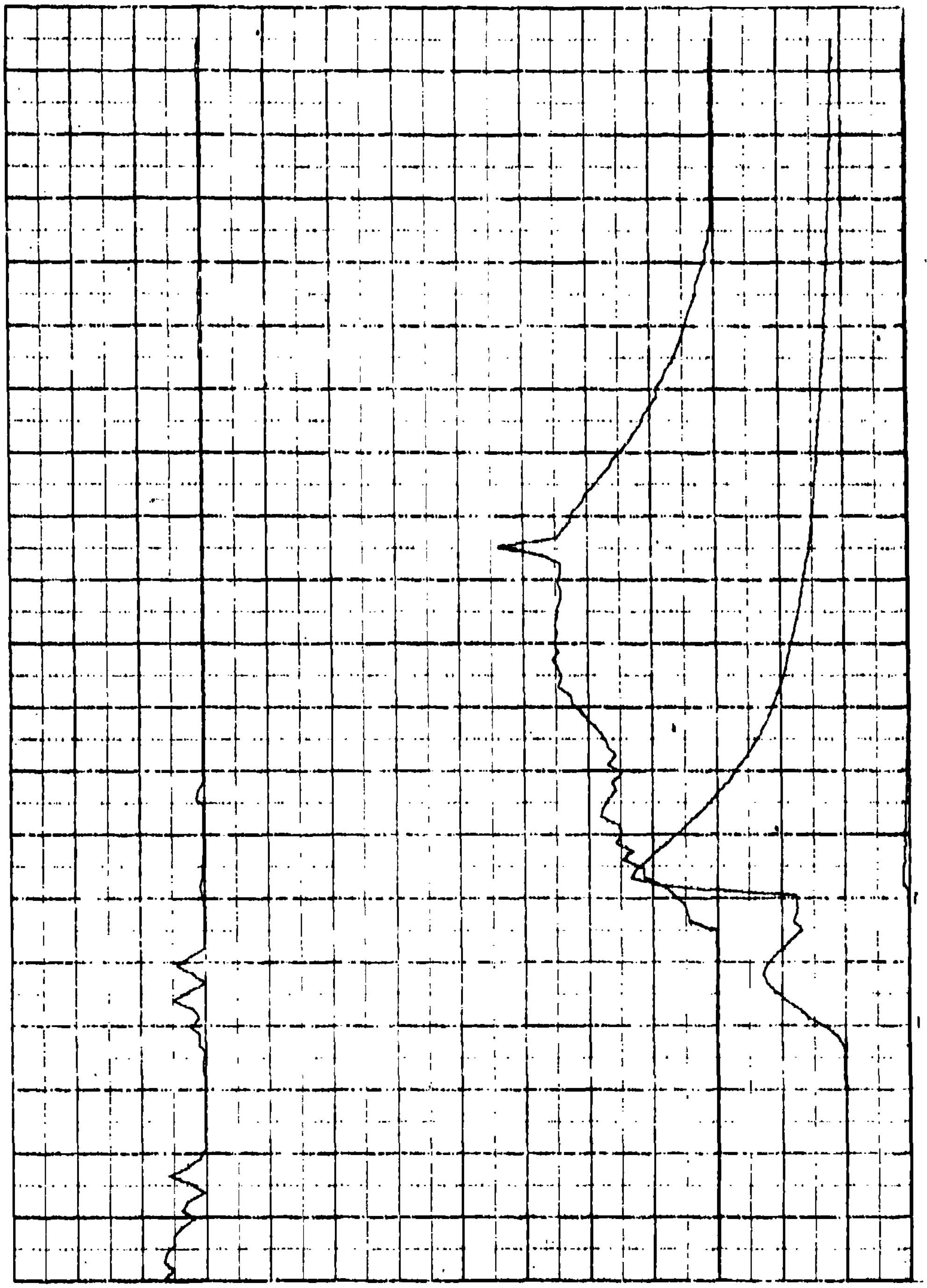
ROUND NO.	PROPELLANT WT (GRAMS) FWD	AFT	INSERT	TOTAL PROP. WT (GRAMS)	IGNITOR WT (GRAMS)
11	96.1	45.6	—	141.7	1.41
12	91.8	45.4	—	137.2	0.75
13	96.6	45.6	—	142.2	1.25
14	96.8	45.5	—	142.3	1.25
15	97.3	45.5	—	142.8	1.25
16	97.3	45.5	—	142.8	1.30 + MYLAR + (2)
17	94.3	45.6	—	139.9	0.75 " "
18	94.3	45.6	—	139.9	1.0
19	98.3	45.4	—	143.7	0.75 + MYLAR + (2)
20	95.3	45.2	—	140.5	0.50 + " + "
21	94.1	45.5	—	139.6	0.50 + " + (4)
22	93.3 (1)	45.5	—	138.8	0.50 + " + (3)
23	94.3 (1)	45.5	—	139.8	0.50 + " + (3)
24	94.5 (1)	45.6	—	139.9	0.50 + " + (3)
25	95.7 (1)	45.6	—	141.3	0.50 + " + (3)

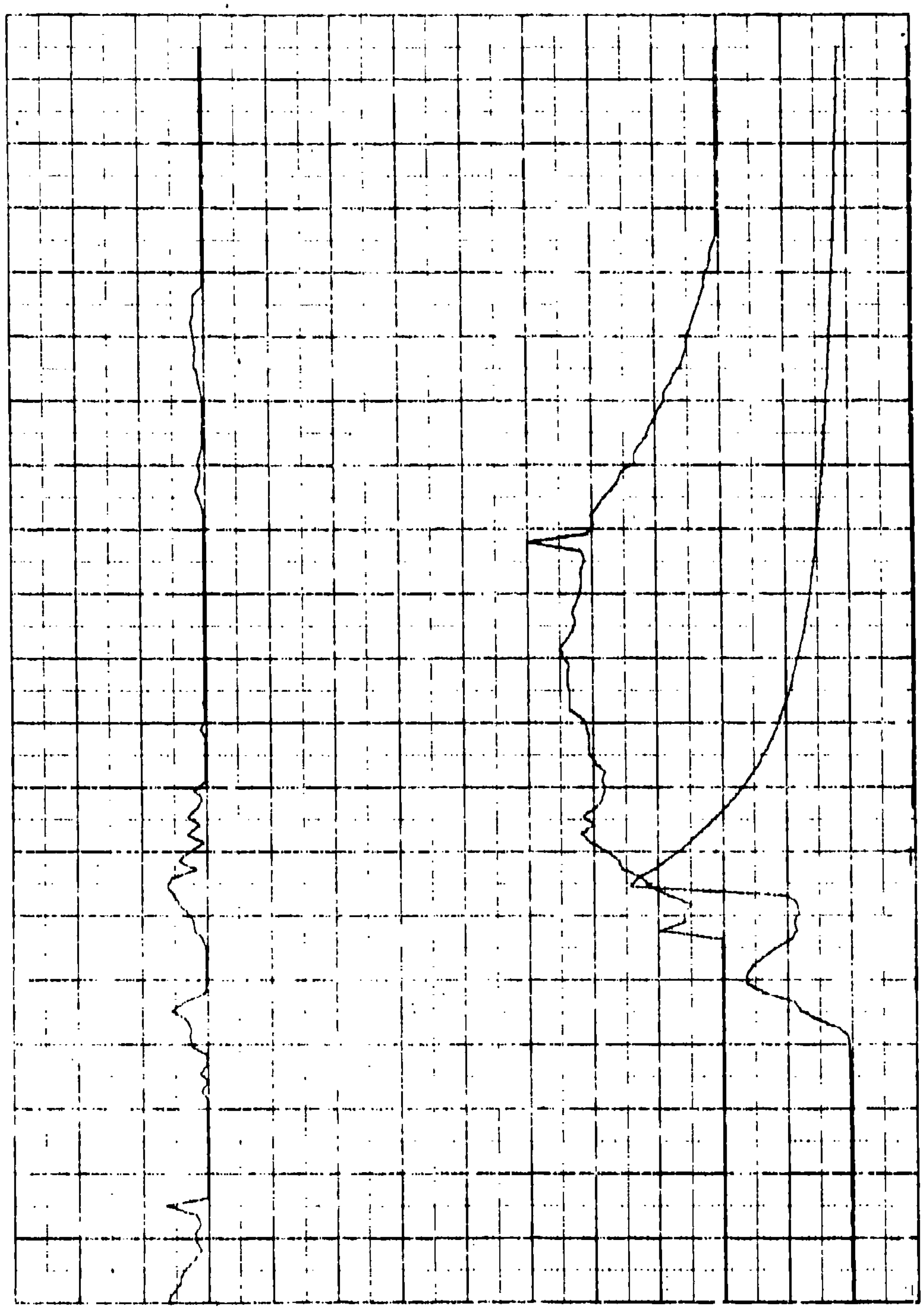
(1) 5479 PROPELLANT.
(2) S&W 0.350" LONG
(3) NYLON SEAL SK300520
(4) 0.1" BRASS SPACER

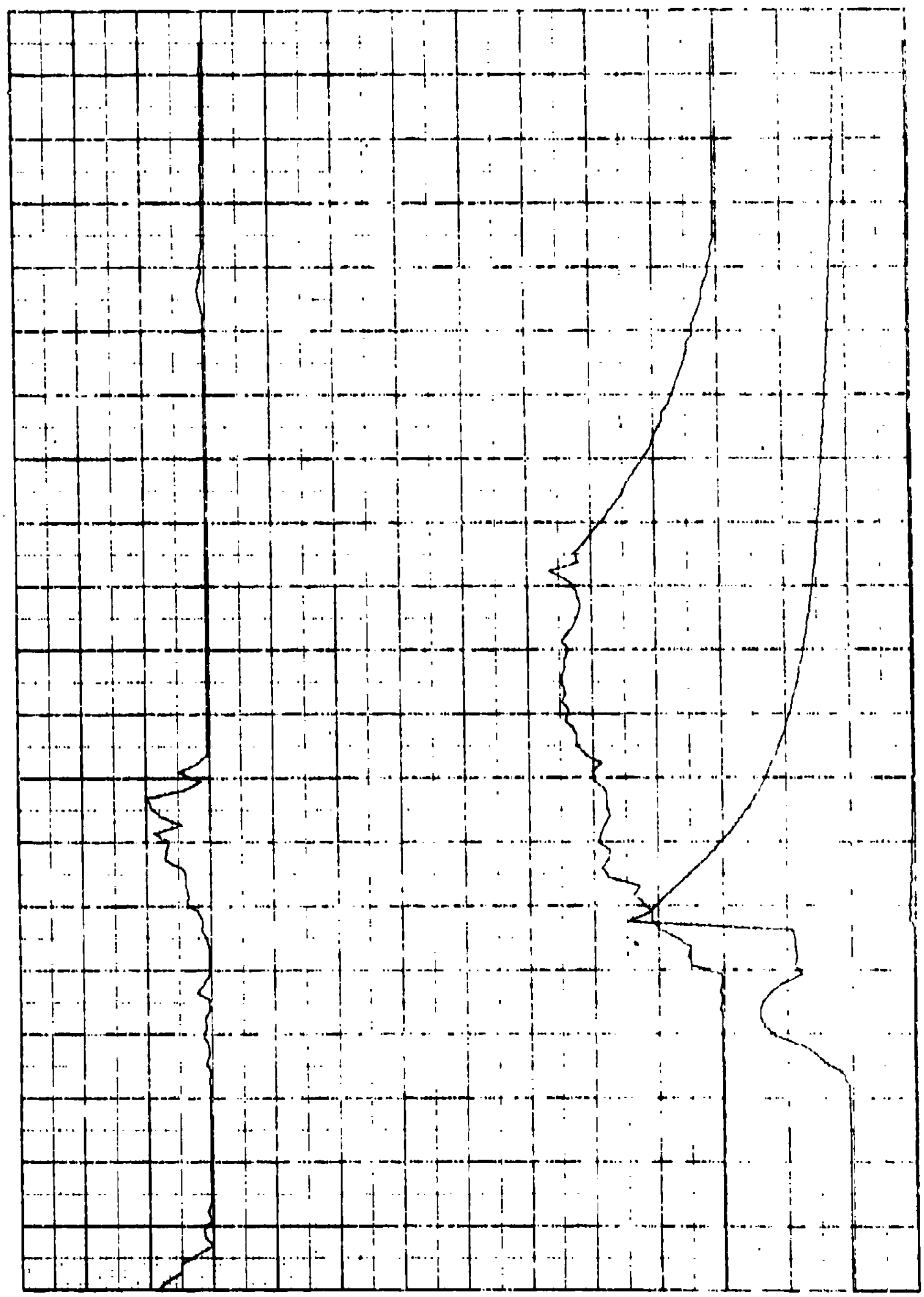
FORM NO. SG-555-81

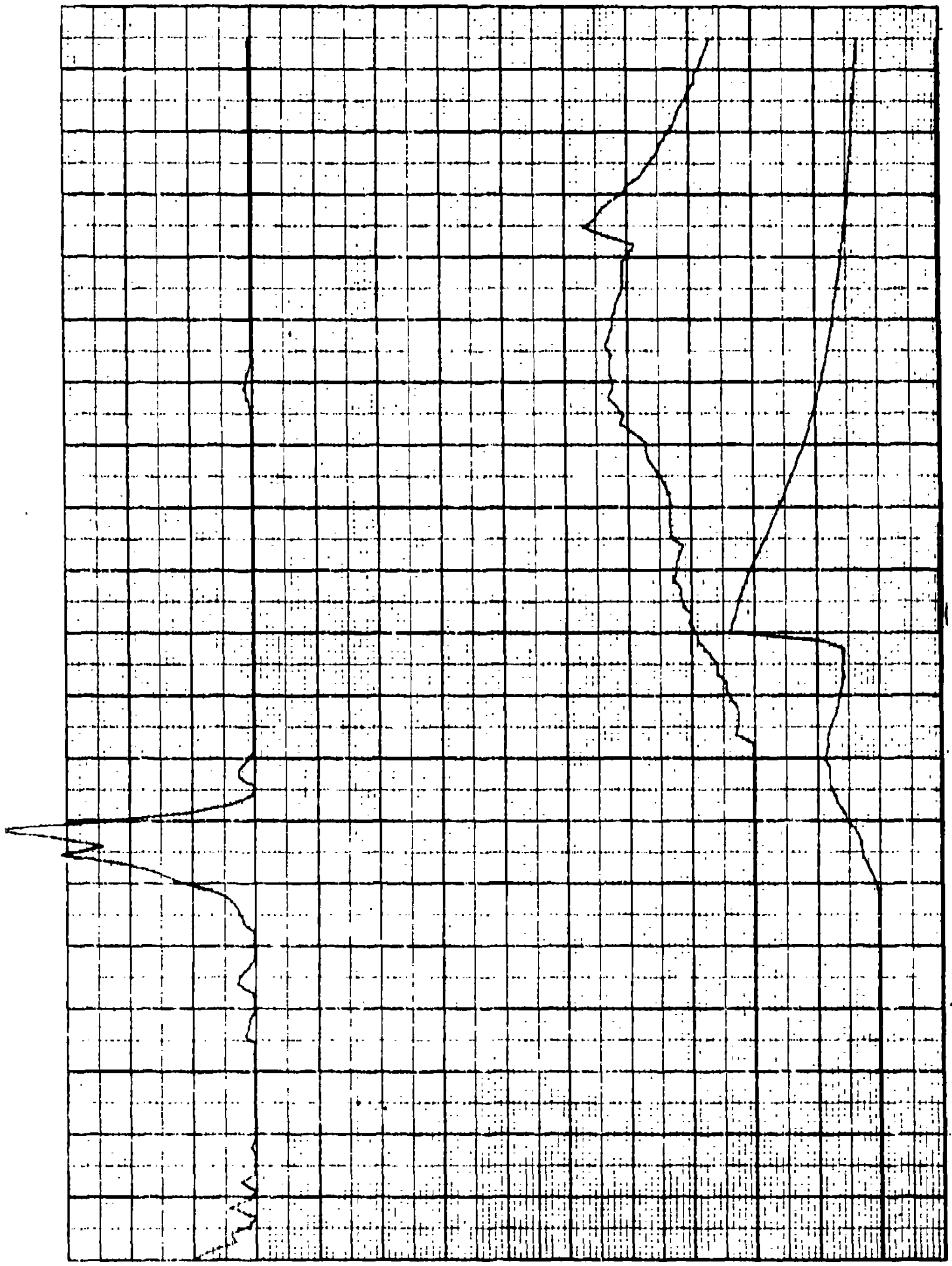


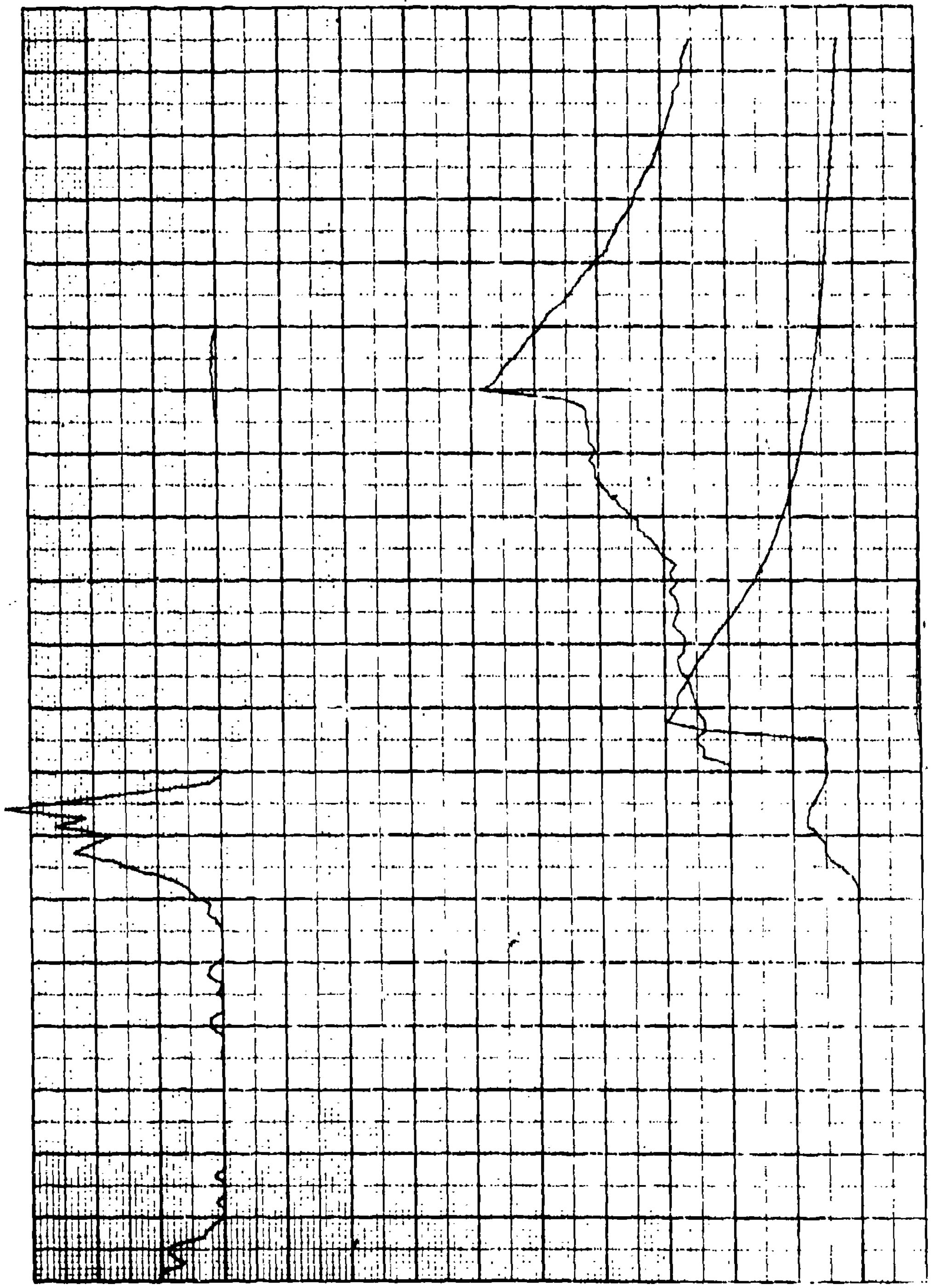


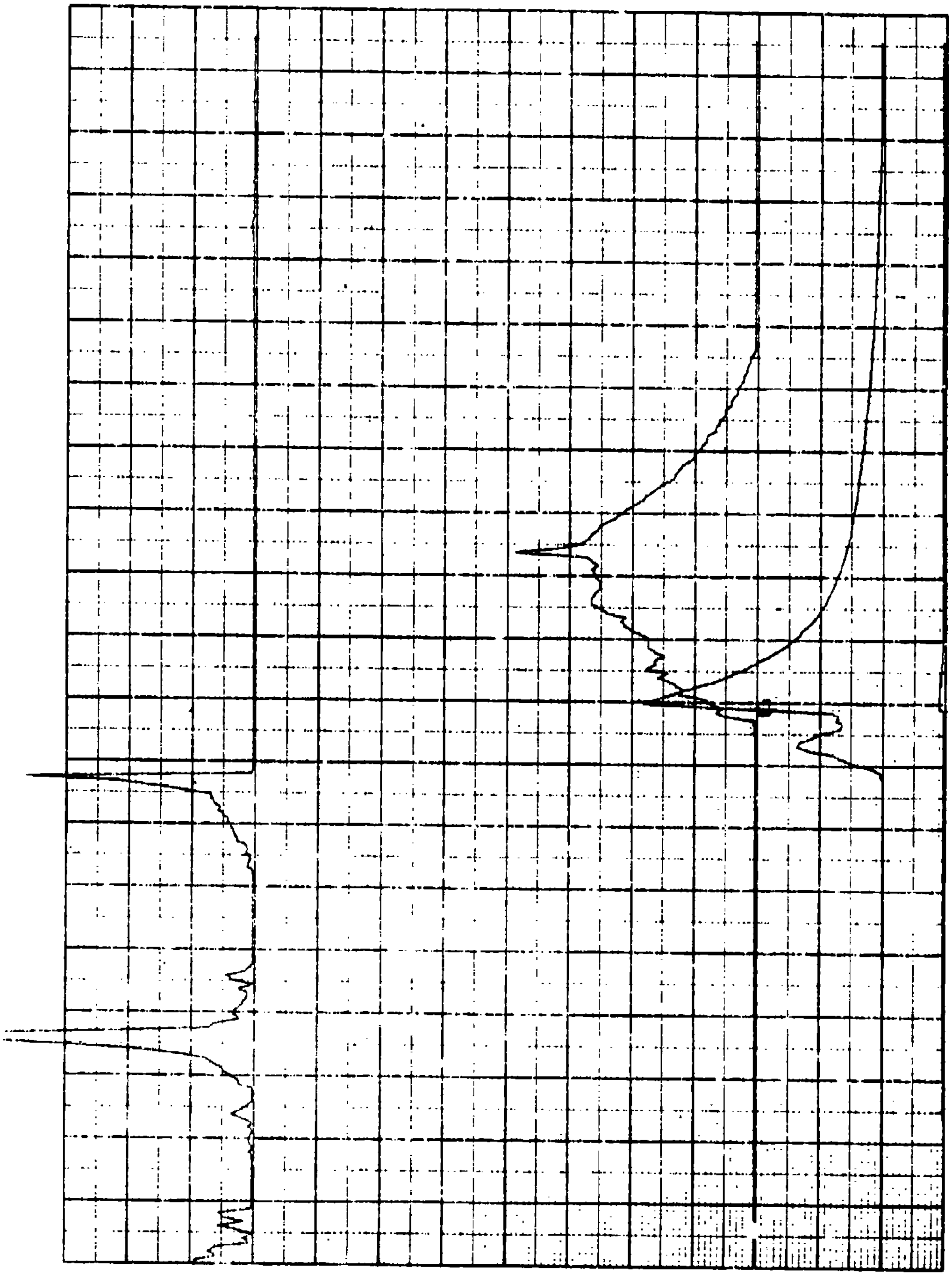


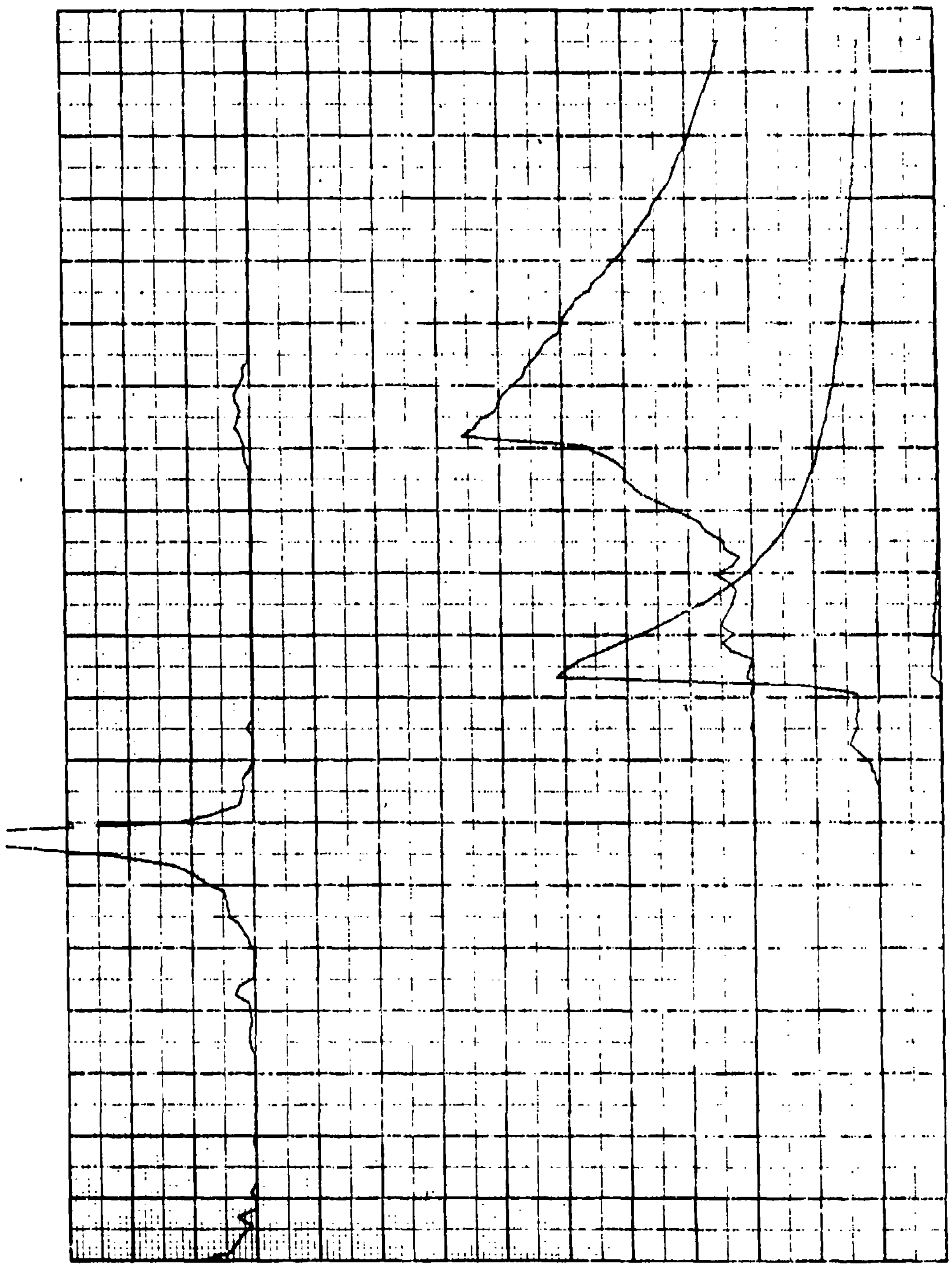


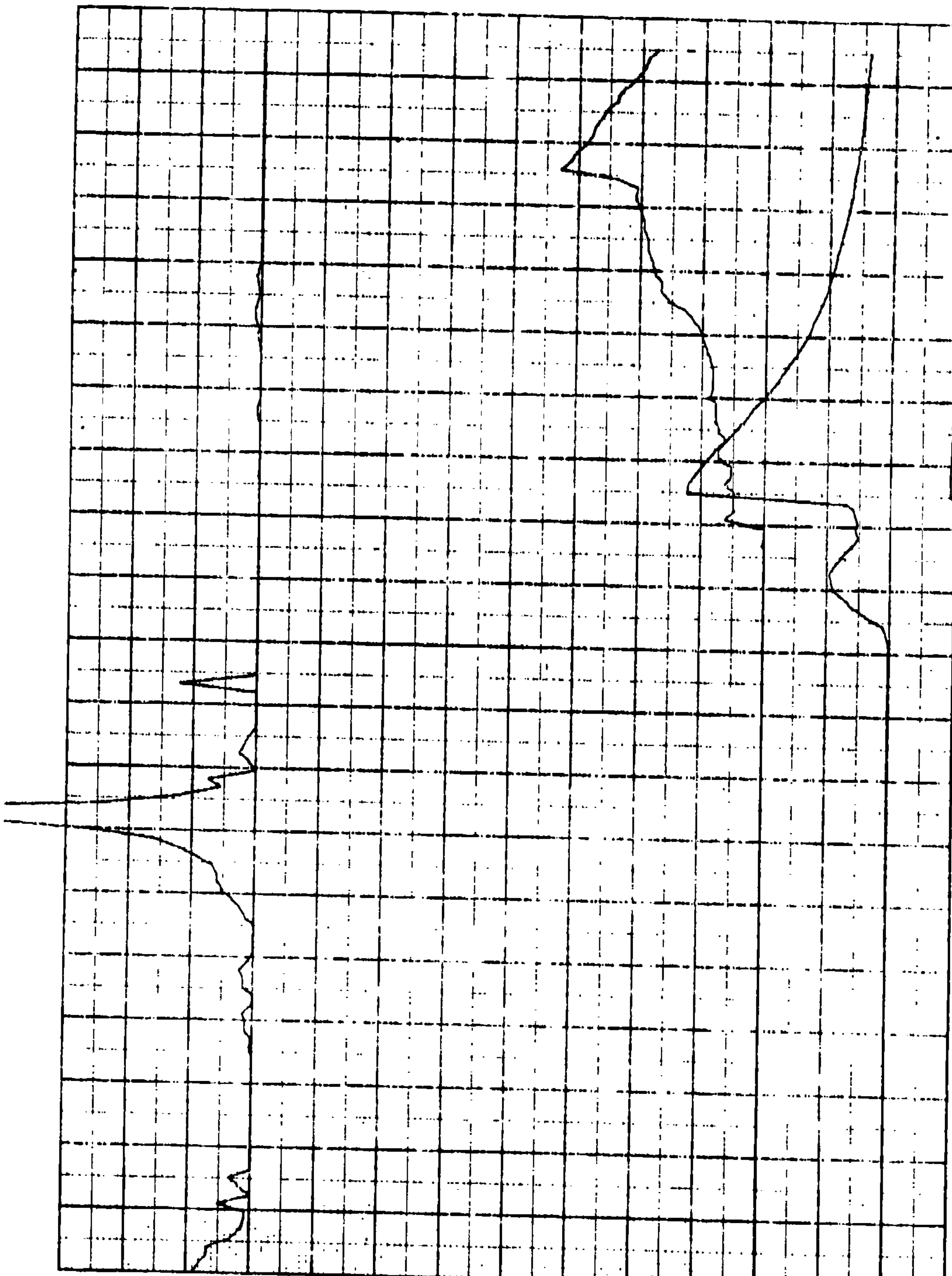


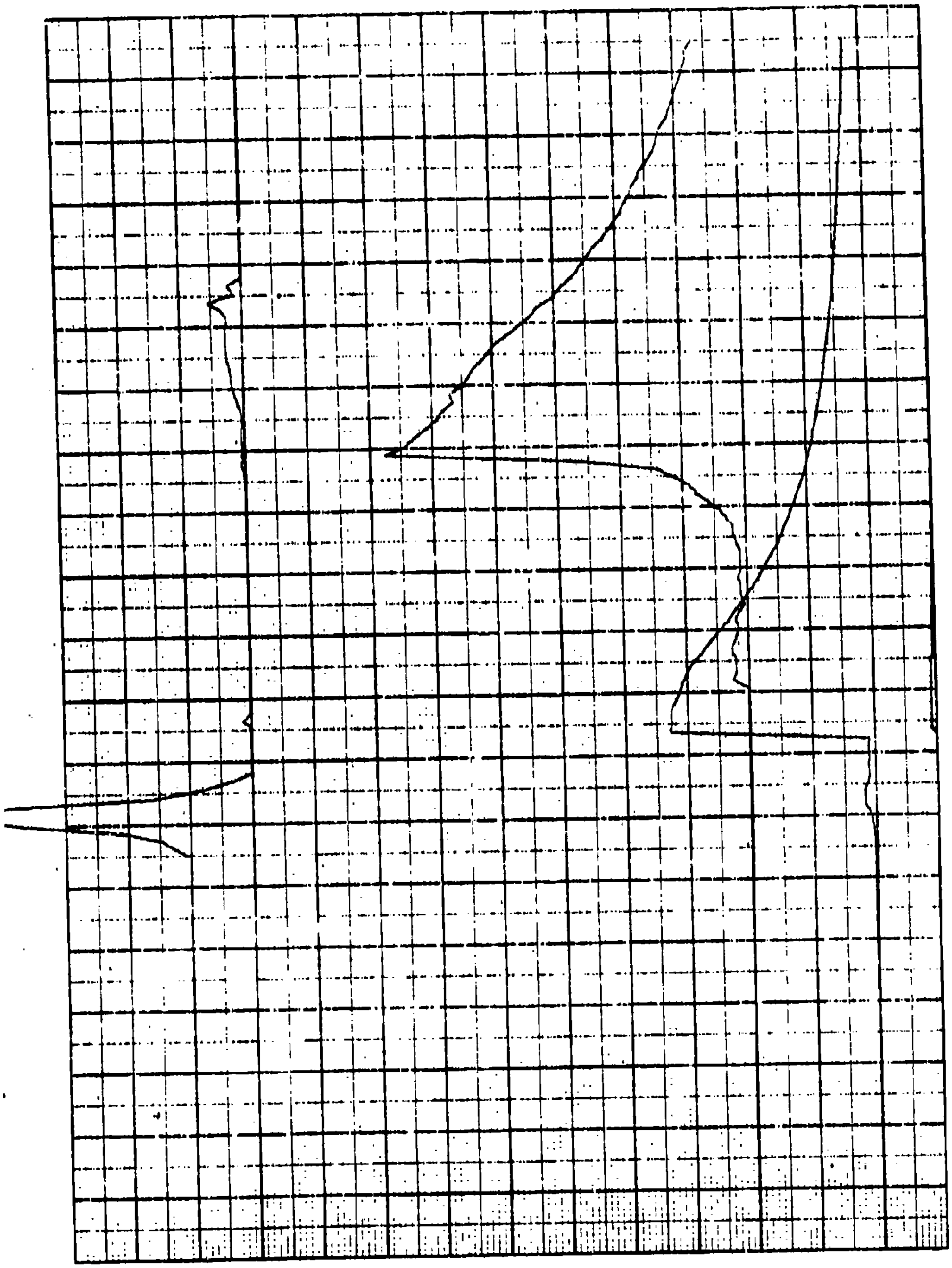


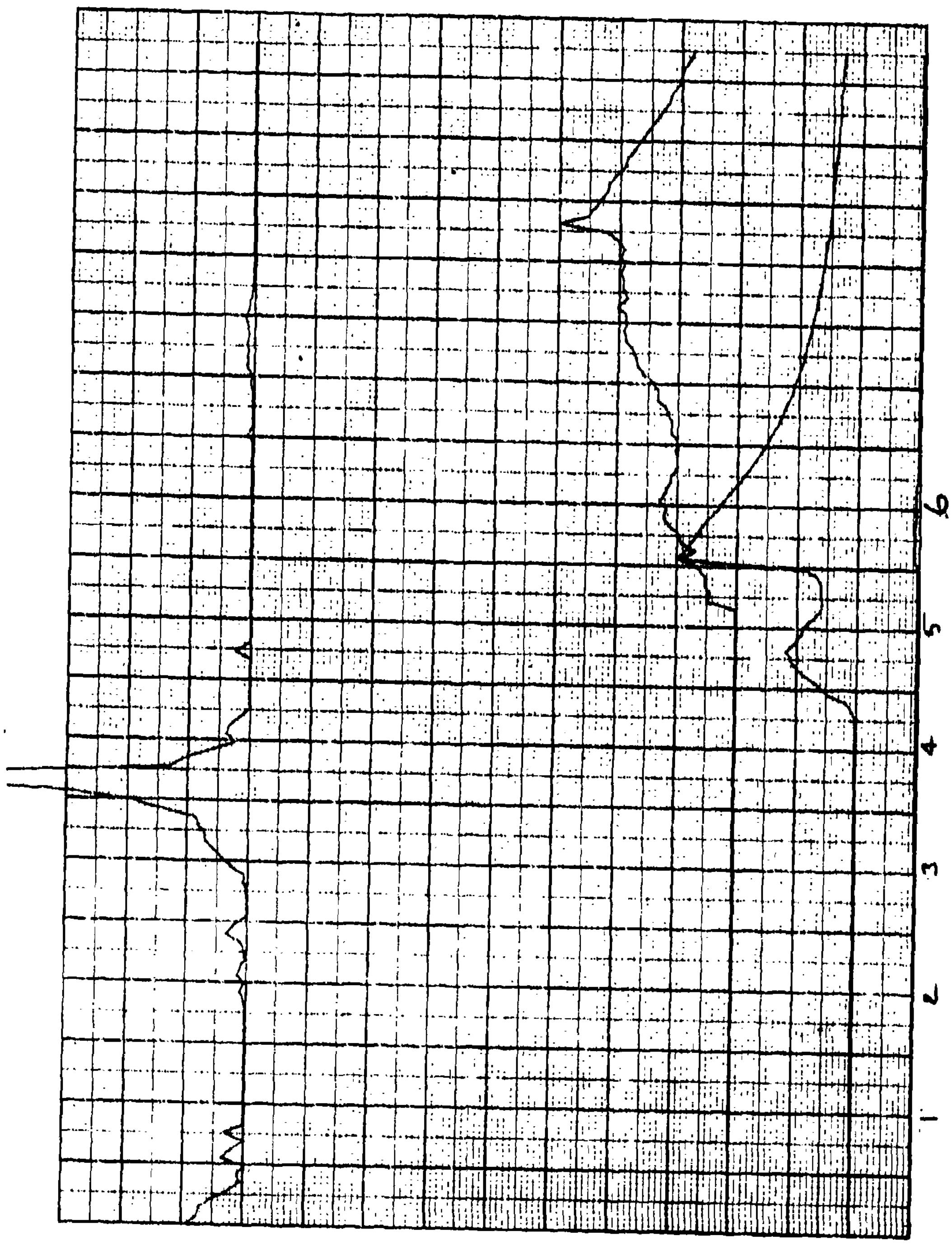








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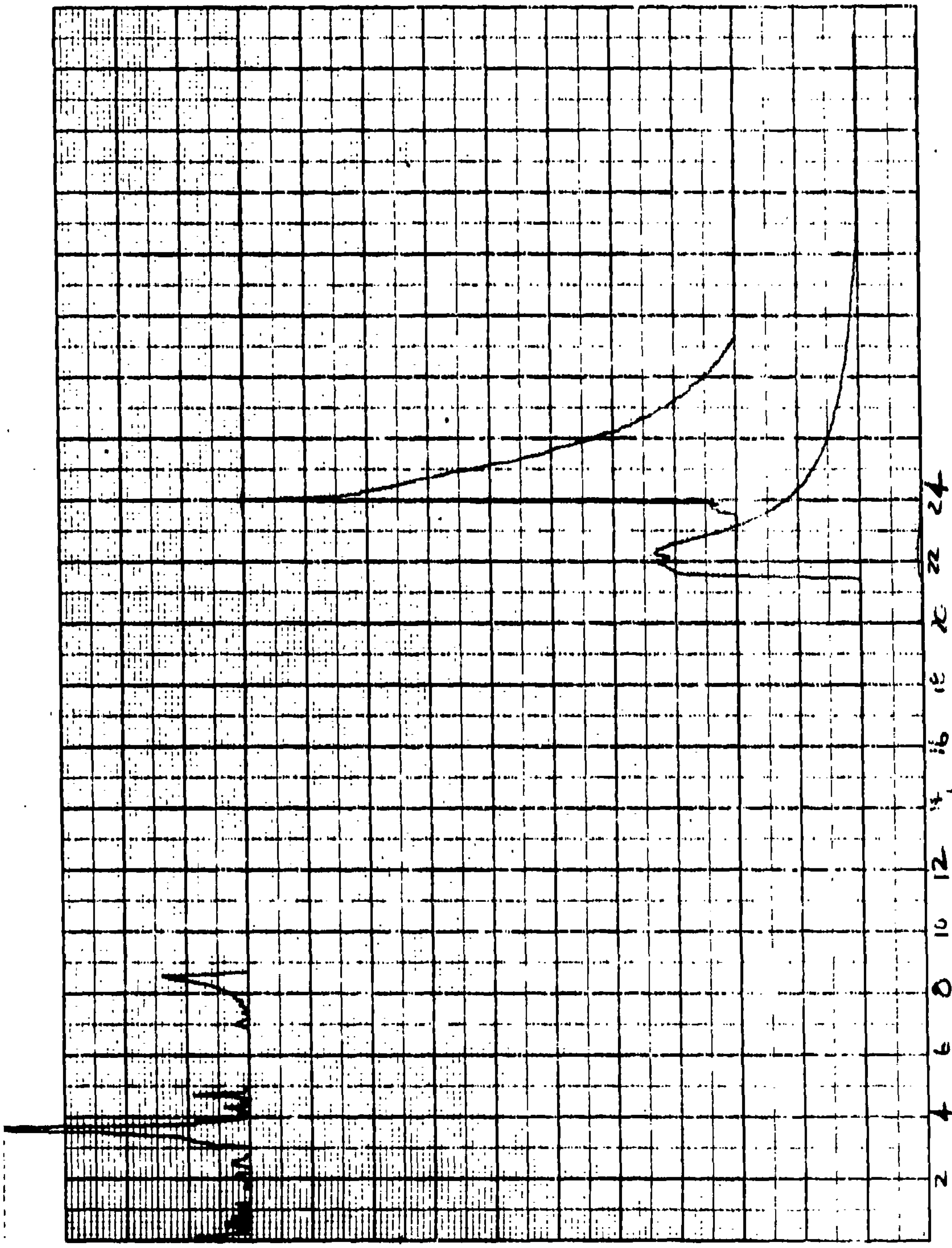
5
4
3
2
1



TEST REPORT

SERIAL NO. 4

OBJECTIVE: To evaluate Class 6 black powder as an ignitor candidate.

REFERENCE: S/N 3

BACKGROUND: The Class 3 black powder evaluated in test series S/N 3 was not satisfactory as an ignitor. The particle size was too large and the resultant rate of gas evolution was too slow to provide the desired shot start cycle. An increase in the rate of gas evolution can be provided through a reduced black powder particle size. Class 6 black powder was selected for this test.

Four rounds were assembled with:

Forward Charge	-	5479 Propellant
Aft Charge	-	8446-9 Propellant
Ignitor	-	Black powder, Class 6
Retention	-	40/10 - NC/Mylar
Primer	-	32 S&W
Case	-	Nylon 12, 30 percent glass

BALLISTIC DATA:

P1 MAX	P2 MAX	P3 MAX	VELOCITY	TIME
Round No. 26				
	36.4	4.5	2830	4.98
		5.73		
ROUND NO-- 27				
-5.1	38.5	4.71	3250	4.7
0	37.84	0		
LS1 TO LS2 3230				
P3 TO LS2 3240				
ROUND NO-- 28				
-.7	35.7	5.06	3156	5.12
0	46.96	1.66		
LS1 TO LS2 3166				
P3 TO LS2 3161				
ROUND NO-- 29				
		Hangfire		

DISCUSSION: Each cartridge was evaluated with a different charge weight of Class 6 black powder to provide a "quick look" approach to the utilization of this granulation. The 1.4 gram charge produced blowby performance and the 0.3 gram charge resulted in a hangfire. The intermediate charges of 0.75 gram and 0.5 gram were also blowby but the magnitude was reduced with the lower charge weight. The test indicated that a charge weight of 0.4 gram of Class 6 black powder would be desirable.

CONCLUSION: Class 6 black powder was a candiate ignitor and should be evaluated in future tests. Inhibition of the aft grain should be evaluated with black powder charge weights greater than 0.4 gram.

The effect of the nylon seals was recommended for further evaluation. The presence of the seal appeared to reduce gas leakage and improve performance.

25MM PLASTIC CASE
AMMUNITION DEVELOPMENT

S/N: 4
DATE: 10 JUNE 74
ENGR: CAREY
AMMO: EATON

OBJECTIVE: TO EVALUATE CLASS 6 BLACK POWDER AS AN IGNITOR CANDIDATE

Test Fixture: IITRI, UNIVERSAL, LIA.
Cartridge Case: Dwg. No. SK 300460, Rev.____, Mat'l NYLON 12, 30% GLASS
Dwg. No. ____, Rev.____, Mat'l ____.
Projectile: Dwg. No. 300347, Rev. A, Plastic Band, 3000 Grain.
Primer: Type PISTOL, Lot No.____, No.____.
Flash Tube: 325GW, 38 Special, ____.
Projectile Retention: 40 Mil NC, 10 Mil Mylar, I3/50 BOND MIT
Ignitor: BP 6, Seals: NONE, NYLON 0.1", BRASS 0.050"
Propellant: Fwd Charge 5479, Lot No. 59-607.
Aft Charge 3446-9, Lot No. 84-63.
Insert —, Lot No. —.

REMARKS: RD NO 26 — NO SPACER, NO. 27 & 28 NYLON SEAL SK300520
NO. 29 BRASS SEAL SK300520

ROUND NO.	PROPELLANT WT (GRAMS) FWD	AFT	INSERT	TOTAL PROP. WT (GRAMS)	IGNITOR WT (GRAMS)
26	94.4 (1)	45.6	—	142.0	1.41
27	95.90	45.4	—	141.3	0.75
28	94.7	45.5	—	140.2	0.60
29	95.1	45.4	—	140.5	0.30

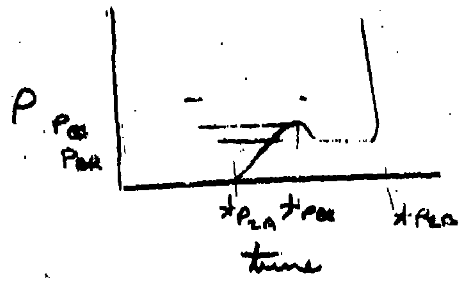
(1) 5473 PROPELLANT

FORM NO. SG-555-81

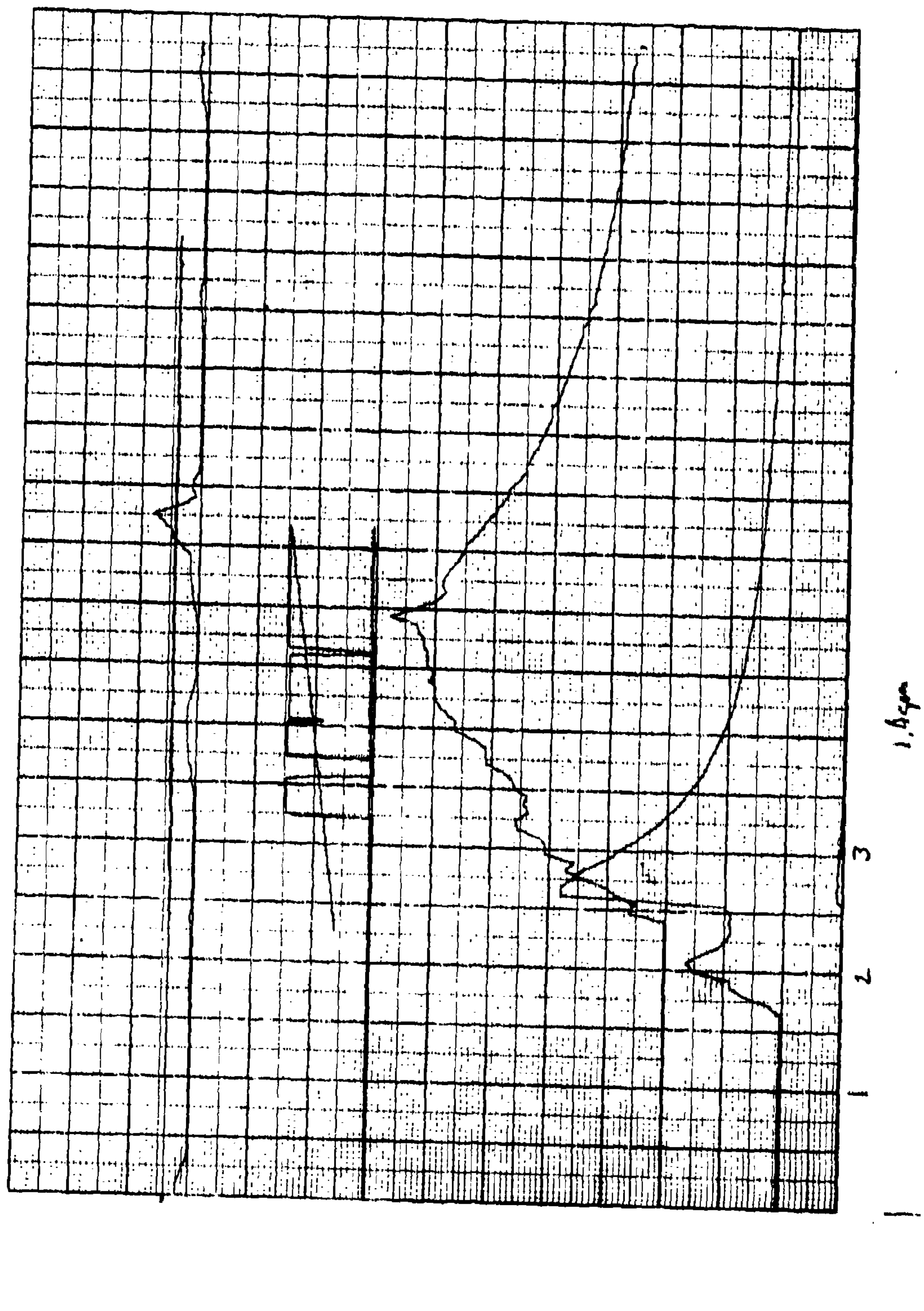
SHOT SHEET LOG

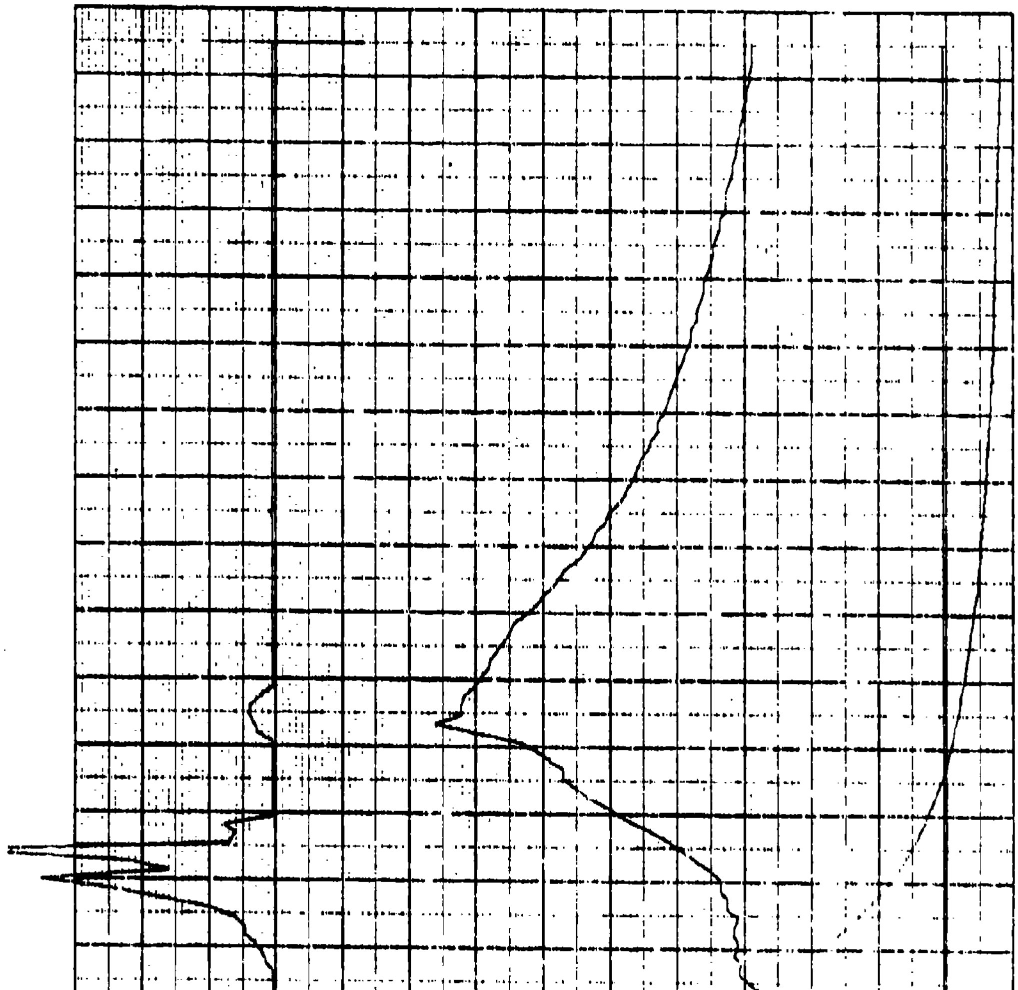
S/N 4

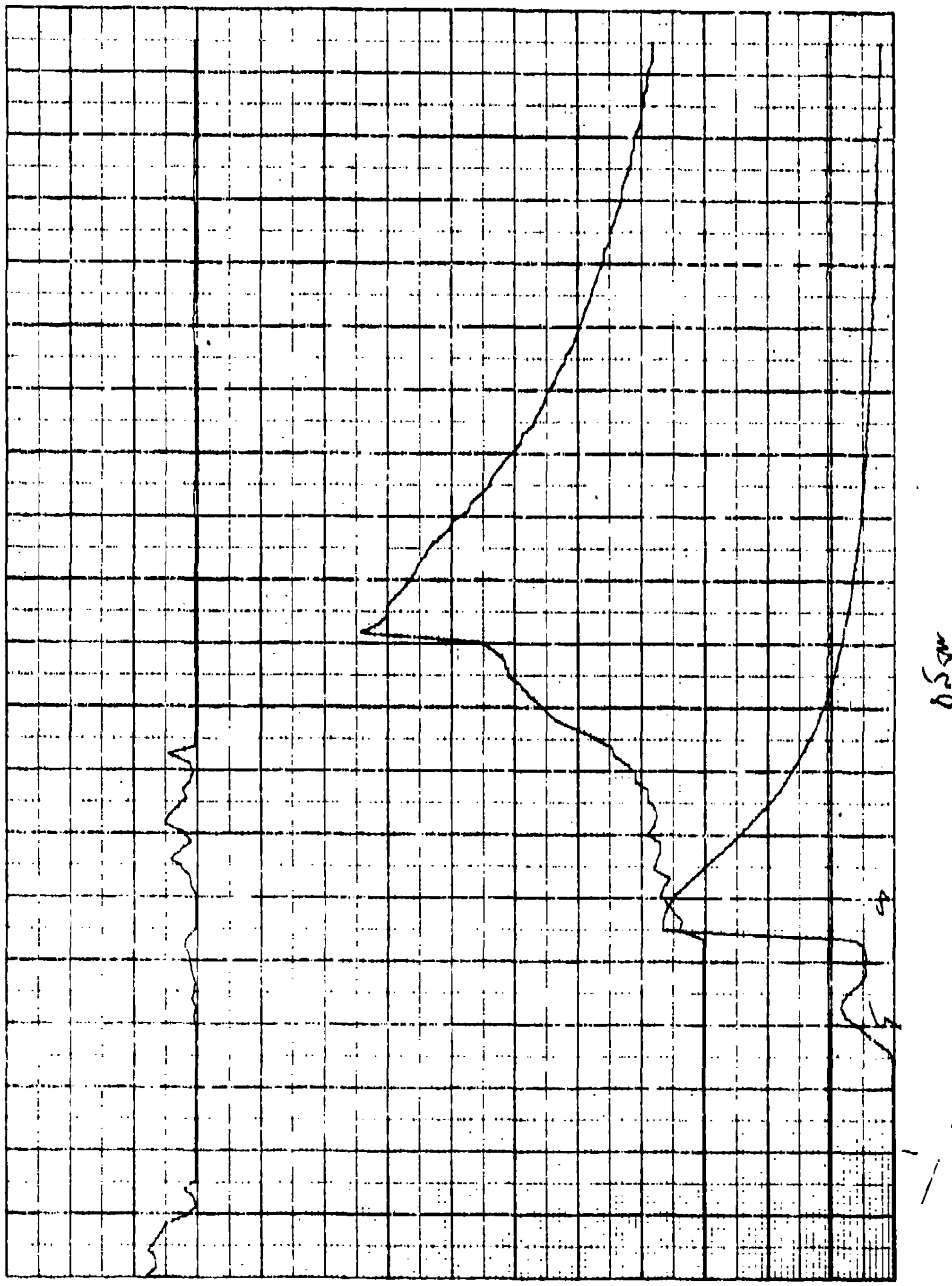
BP_6



Rd No	P_{BB} (KPSI)	t_{P2A} (MS)	P_{BR} (KPSI)	t_{PRB} (MS)	V_{19} (FPS)	IGNITOR (gms)
						BP_6
26	16	1.6	9	2.5	2830	1.40
27	9	1.4	5	2.3	3250	0.75
28	8	1.7	5	2.7	3156	0.50
29	-- HANGFIRE --					0.30


1,6cpm
3
2
1





TEST REPORT

SERIAL NO. 5

OBJECTIVE: To evaluate ignitor TMS 300432 and the effect of brass seals on ballistic performance.

REFERENCE: S/N 1

BACKGROUND: Test series S/N 1 was fired in the IITRI test fixture with ignitor TMS 300432. The test results indicated that 0.1 gram of ignitor was the desired charge weight for the best performance. Differences between the IITRI and the Universal test fixtures necessitated a repeat evaluation of the ignitor to verify the performance.

Five rounds were assembled with:

Forward Charge	-	5479 Propellant
Aft Charge	-	8446-9 Propellant
Ignitor	-	TMS 300432
Retention	-	40/10 - NC/Mylar
Primer	-	32 S&W
Case	-	Nylon 12, 30 percent glass
Seal	-	Brass

BALLISTIC DATA:

```
P1 MAX      P2 MAX      P3 MAX      VELOCITY     TIME
-------------------------------------------------------
Round No. 30
                   Misfire (Projectile In Barrel)

ROUND NO-- 31
    .1          47.6        4.43        3419      3.88
    0           48.25       3.35
LS1 TO LS2 3366
P3 TO LS2 3392
ROUND NO-- 32
    47.4        -.1         4.24        3455      4.91
    43.96       0           2.51
LS1 TO LS2 3482
P3 TO LS2 3428
ROUND NO-- 33
    49.8        -.2         4.22        3491      3.95
    44.89       0           1.99
LS1 TO LS2 3476
P3 TO LS2 3484
ROUND NO-- 34
    49          -.2         7.19        4001      33.2  No Seal
    56.25       0           0
LS1 TO LS2 4046
P3 TO LS2 4023
```

DISCUSSION: Comparison of the ballistic performance recorded in this test series with the data from S/N 1 indicated that there was a difference between the two test fixtures. The 0.1 gram of ignitor charge produced a misfire. The projectile was forced into the barrel but the propellant failed to ignite. The ignitor charge weight was increased to 0.3 gram and over-ignition blowby performance was observed. Subsequent reductions in charge weight reduced the blowby and one cartridge without a brass seal yielded a long action of 33 milliseconds.

Examination of the fired cartridge cases showed evidence that the brass seal interfered with the projectile travel. Each seal was badly distorted and the seals were forced into the barrel entrance cone. The seal appeared to restrain the projectile momentarily at the barrel entrance. The action induced a rapid change in the free volume of the shot start cycle and forced the pressure to rise accordingly. The pressure increased the blowby and over-ignition of the charge. The result was a relatively fast action time 4 to 5 msec, velocities of 3500 fps and blowby. The increase in velocity and the reduction in action time were not considered a normal ballistic cycle. The brass seal was determined to upset the interior ballistic cycle.

The cartridge length was machined at 6.105 inches and 6.155 inches to provide 0.050 and 0.100 inch of crush up. The 0.050 inch of crush up was observed to be compatible to case performance. The 0.1 inch cracked the case that resulted in a gas burn on the chamber face. The next long cartridge was crushed up such that a 0.015 inch gap remained at the breech face. The case side wall flowed into the gap 120° around the base and eroded away the remaining 60 degree portion of the base. Ballistic performance of the cartridge did not appear to be effected by the gas leak.

CONCLUSION: The brass seal was observed to have a significant influence on cartridge performance. Techniques designed to provide an interference interface with the projectile travel without damage to the projectile are recommended for further evaluations.

Ignitor TMS 300432 at a charge weight of 0.15 gram was selected as a baseline charge.

25MM PLASTIC CASE
AMMUNITION DEVELOPMENT

S/N: 5
DATE: 14 JUNE 74
ENGR: CAREY
AMMO: EATON

OBJECTIVE: TO EVALUATE 432 IGNITOR WITH BRASS SEALS

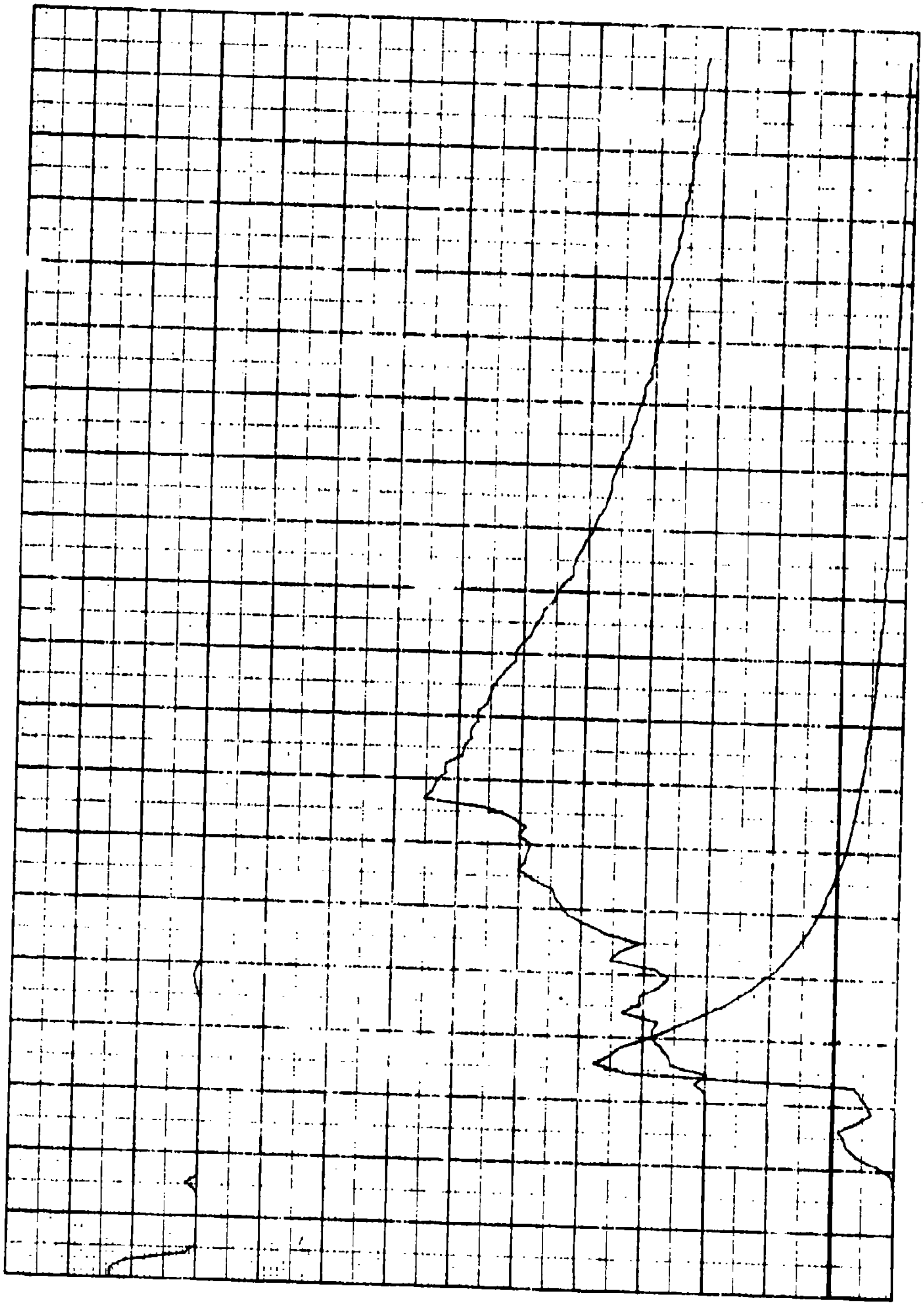
Test Fixture: IITRI, UNIVERSAL, RIA.
Cartridge Case: Dwg. No. SK 300460 Rev.____, Mat'l NYLON 12, 30% GLASS
Dwg. No.______, Rev.____, Mat'l______.
Projectile: Dwg. No. 300347, Rev. A, Plastic Band, 3000 Grain.
Primer: Type PISTOL, Lot No.______, No.______.
Flash Tube: 25MM, 38 Special, ______.
Projectile Retention: 40 Mil NC, 10 Mil Mylar, ISI 60 BOND
Ignitor: TMS432, Seals: BRASS, SK 300520
Propellant: Fwd Charge 5029, Lot No. 49-607.
Aft Charge 5026-9, Lot No. 89-63.
Insert —, Lot No. —.

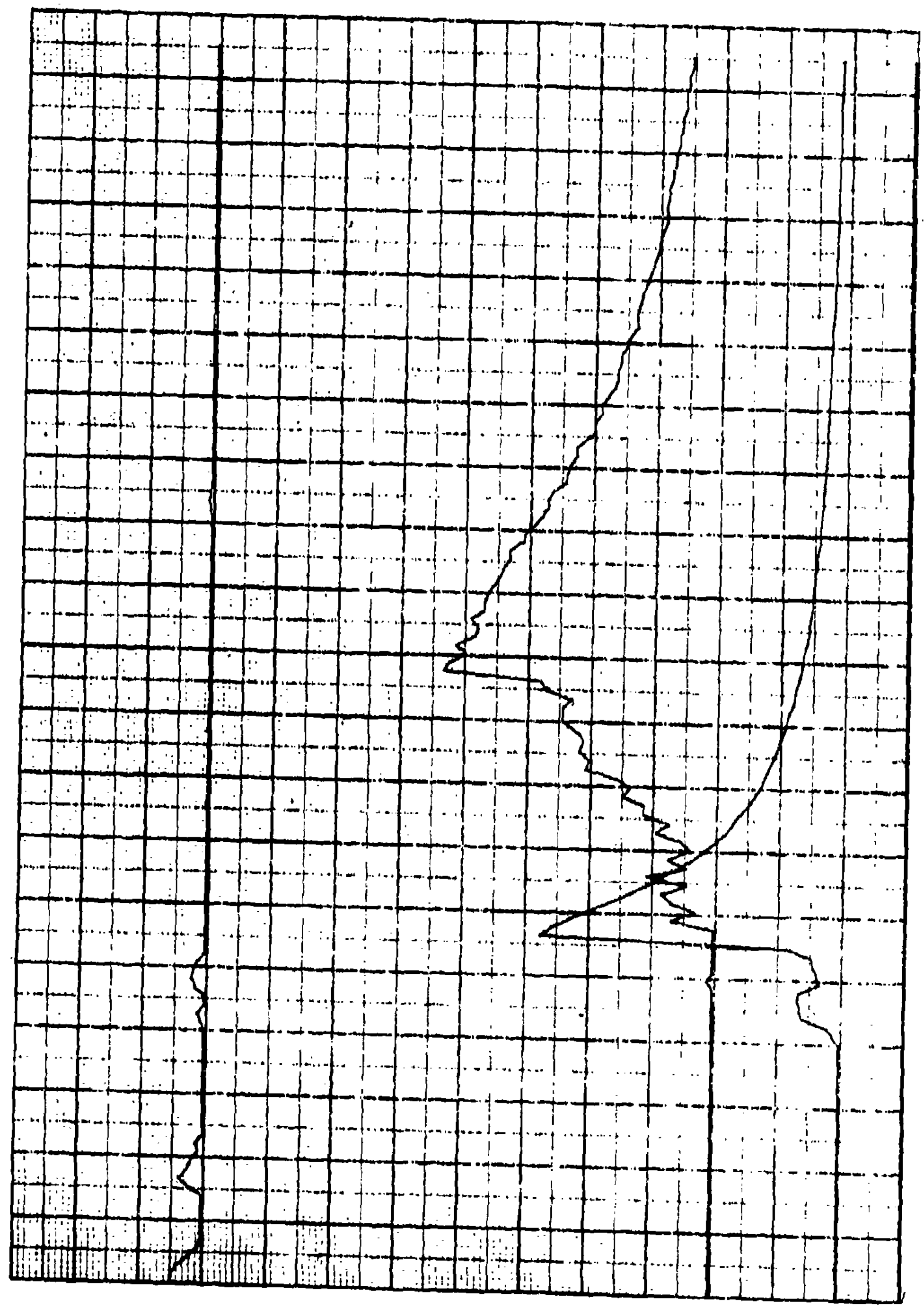
REMARKS: Rd. No. 30 & 31 0.05" CRUSH UP, No. 32, 33 0.1" CRUSH UP. No. 34 CARDBOARD – NO CRUSH UP

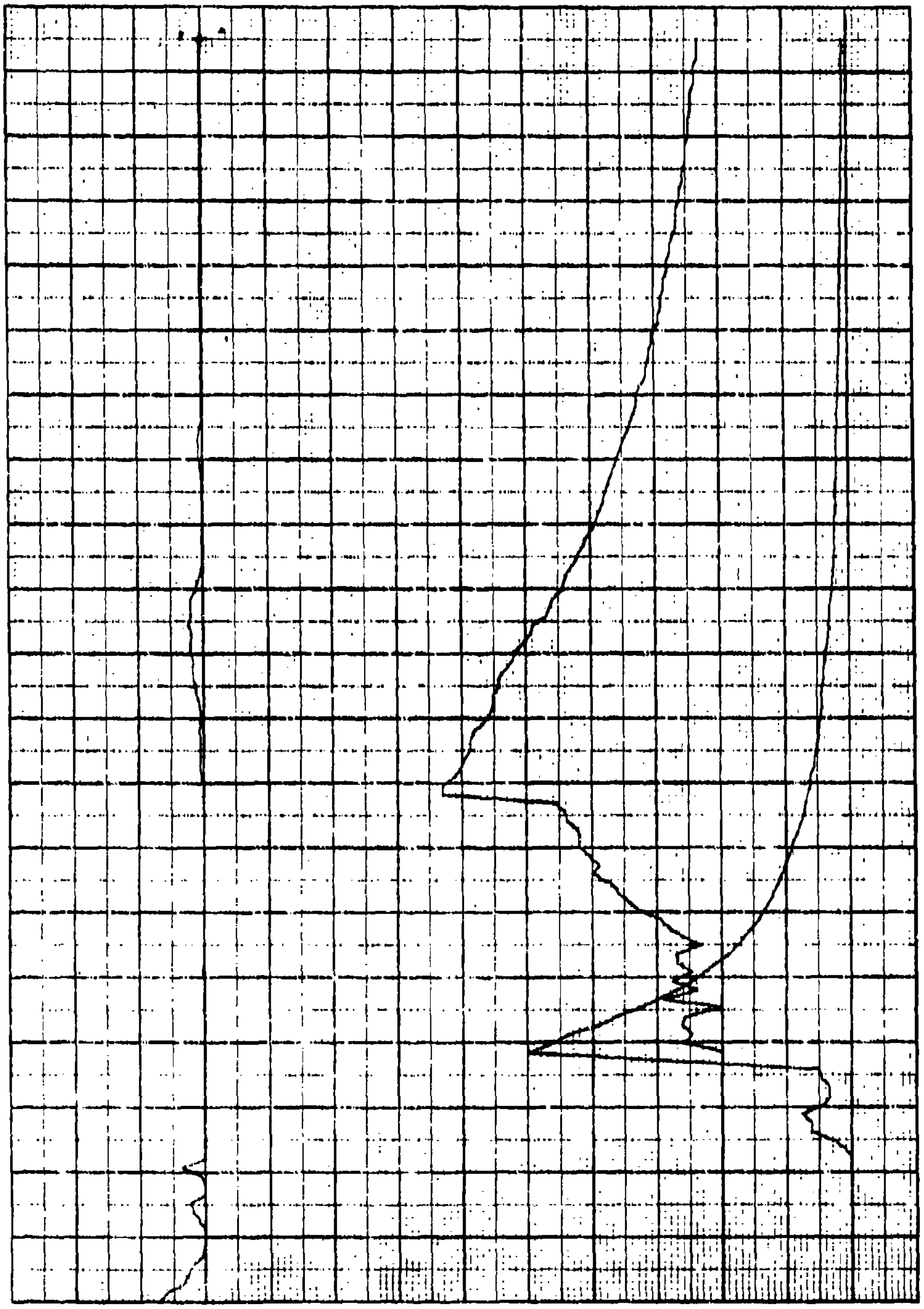
ROUND NO.	PROPELLANT WT (GRAMS) FWD	AFT	INSERT	TOTAL PROP. WT (GRAMS)	IGNITOR WT (GRAMS)
					432
30	95.1	45.5	—	140.6	0.10
31	94.3	45.5	—	139.8	0.30
32 (2)	96.0	45.5	—	141.5	0.20
33	96.3	45.5	—	141.8	0.15
34 (1)	96.1	45.5	—	141.8	0.15

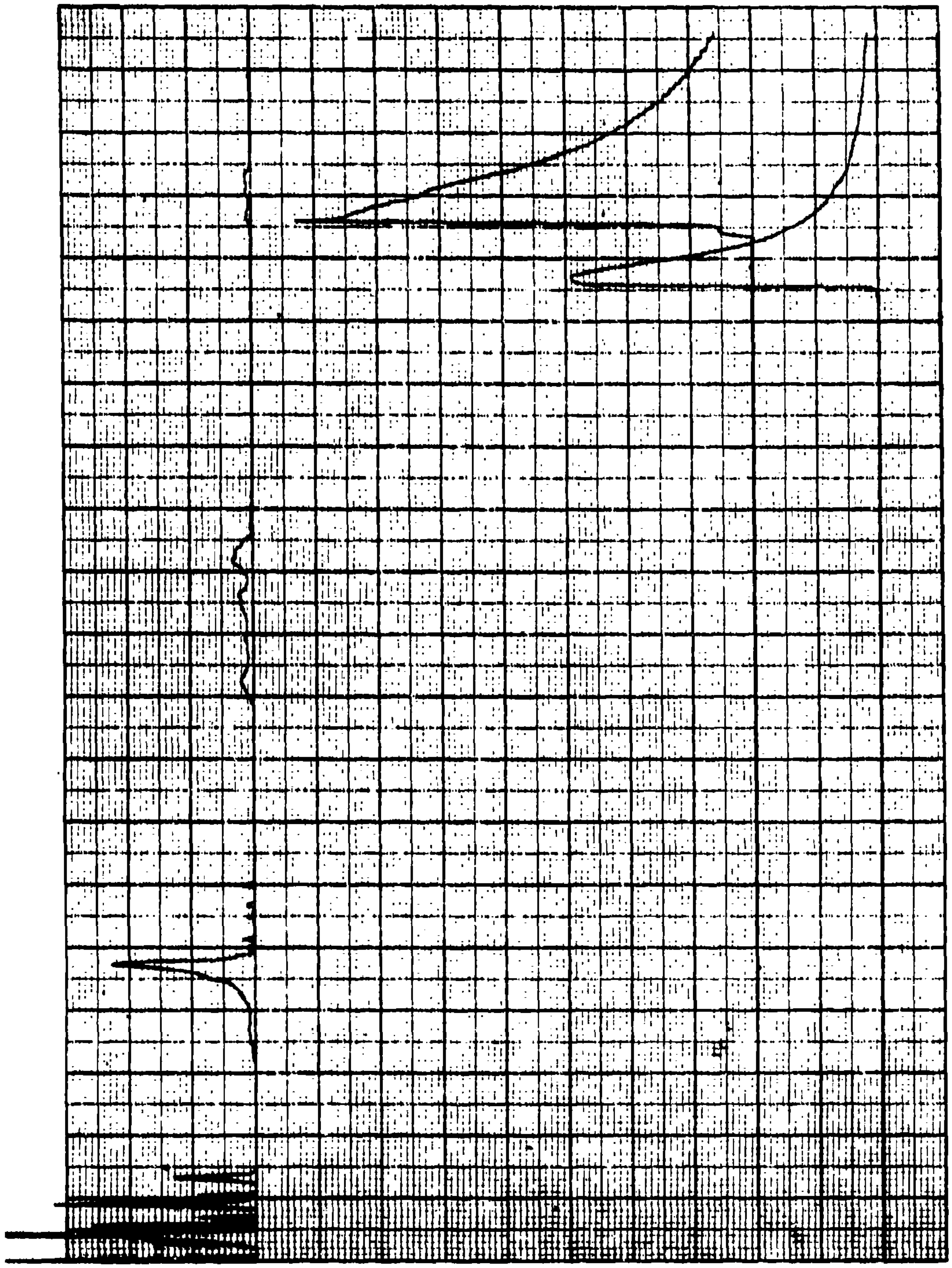
(1) NO SEAL
(2) 0.015" GAP LEFT BETWEEN CHAMBER & BOLT.

FORM NO. SG-555-81









TEST REPORT

SERIAL NO. 6

OBJECTIVE: To evaluate an epoxy/glass filament wound cartridge case.

REFERENCE: S/N 5

BACKGROUND: The glass filament wound concept was selected as a case candidate to represent the thermoset family of materials. Two cases were fabricated at the Brunswick Plant in Lincoln, Nebraska by a standard process used in the manufacture of filament wound pipe. The cases were machined at each end to accept a steel head and a steel forward seal as shown in Figure 1. The ends were bonded to the case with an epoxy adhesive. The cartridge length was 6.050 inches. The chamber length was 6.055 inches.

Two cartridges were assembled with:

Forward Charge	-	5479 Propellant
Aft Charge	-	8446-9 Propellant
Ignitor	-	TMS 300432
Retention	-	40/10 - NC/Mylar
Primer	-	32 S&W
Case	-	Epoxy/glass
Seal	-	Steel

BALLISTIC DATA:

```
P1 MAX     P2 MAX     P3 MAX     VELOCITY     TIME
---------------------------------------------------
ROUND NO-- 35
  36.7       -.2
  51.48      0         5.98        3529        4.7
                        .94
LS1 TO LS2 3514
P3 TO LS2 3521
ROUND NO-- 36
  36.4       0
  54.88      0         6.31        3529        4.91
                       1.43
LS1 TO LS2 3476
P3 TO LS2 3502
```

DISCUSSION: The ballistic data was very consistent between the two tests. The blowby recorded on the barrel pressure transducer was 2000 psi and approximately 7 Kpsi lower than normally observed. Examination of the fired cases indicated that the forward seal I.D. was deformed outward against the barrel. The seal appeared to obturate with the projectile prior to engraving. The area around the projectile was reduced and the blowby gases were blocked. Shot start cycle efficiency was improved resulting in very reproducible ballistic performance.

The steel seals were wedged against the chamber wall and prevented the cartridge case from being easily withdrawn from the chamber. The filament wound portion of the case was extracted intact without damage.

CONCLUSION: The filament wound concept is feasible but will require design changes in the steel ends to accommodate extraction from the gun chamber.

The forward seal appeared to have a significant effect on ballistic performance and performance variations. An interference seal concept is recommended for further development evaluations.

25MM PLASTIC CASE
AMMUNITION DEVELOPMENT

S/N: 6
DATE: 19 JUNE 76
ENGR: CARY
AMMO: EATON

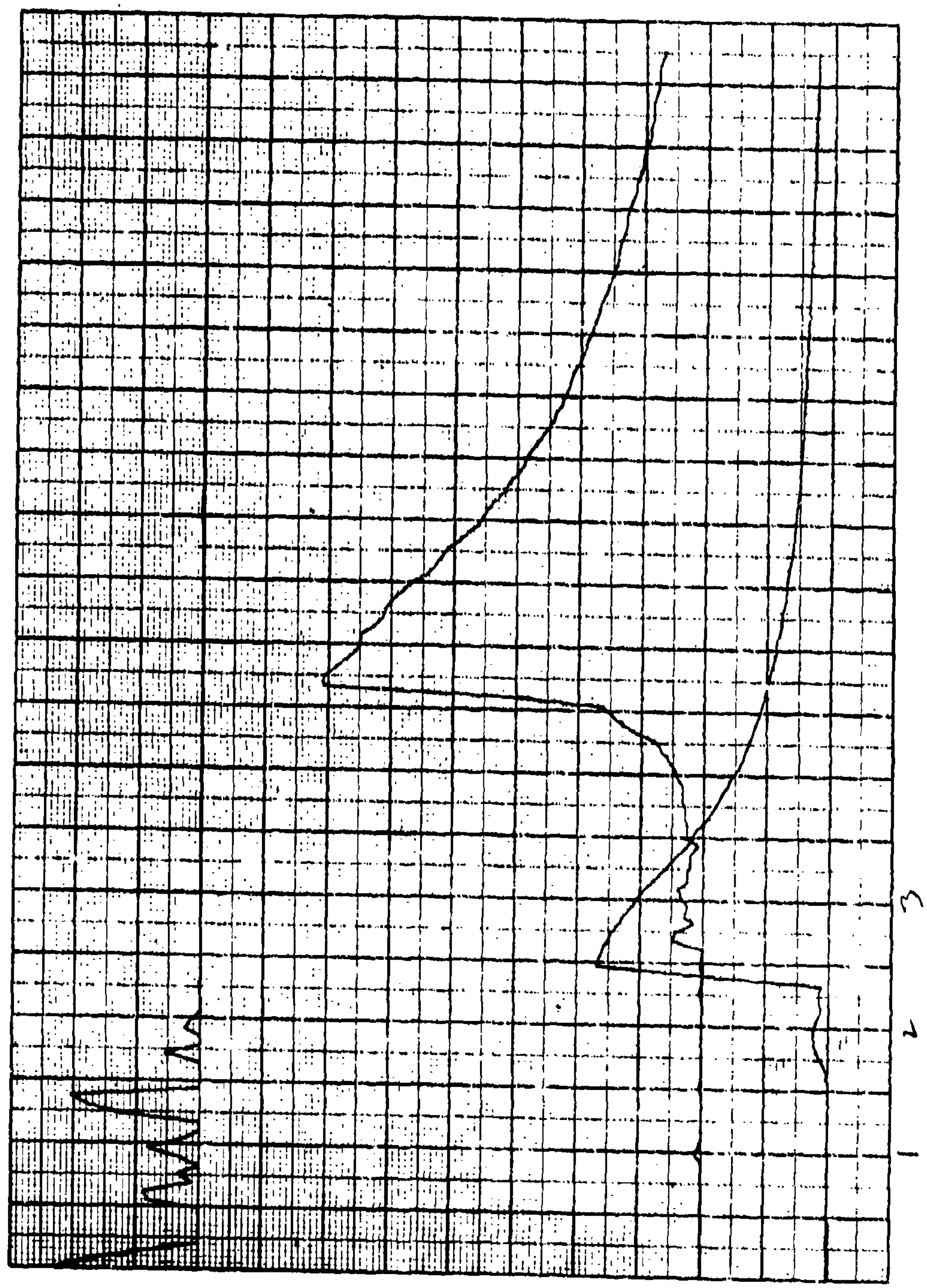
OBJECTIVE: TO EVALUATE AN EPOXY/GLASS FILAMENT WOUND CASE CONCEPT

Test Fixture: IITRI, UNIVERSAL, RIA.
Cartridge Case: Dwg. No. SK 300460, Rev.____, Mat'l______.
Dwg. No. ______, Rev.____, Mat'l Epoxy/Glass
Projectile: Dwg. No. 300347, Rev. A, Plastic Band, 3000 Grain.
Primer: Type______, Lot No.______, No.______.
Flash Tube: 3256W, 38 Special, ______.
Projectile Retention: 40 Mil NC, 10 Mil Mylar, ____ Mil Loctite 35/50
Ignitor: TMS 300432, Seals: Steel
Propellant: Fwd Charge 5479, Lot No. 59-616,
Aft Charge 8446-9, Lot No. 87-607,
Insert N/A, Lot No.______.

REMARKS: CARTRIDGE LENGTH 6.050 INCHES — NO CRUSH UP

ROUND NO.	PROPELLANT WT (GRAMS) FWD	AFT	INSERT	TOTAL PROP. WT (GRAMS)	IGNITOR WT (GRAMS)
					TMS 432
35	99.6	36.6	—	136.2	0.15
36	100.0	36.5	—	136.5	0.15

FORM NO. SG-555-81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2
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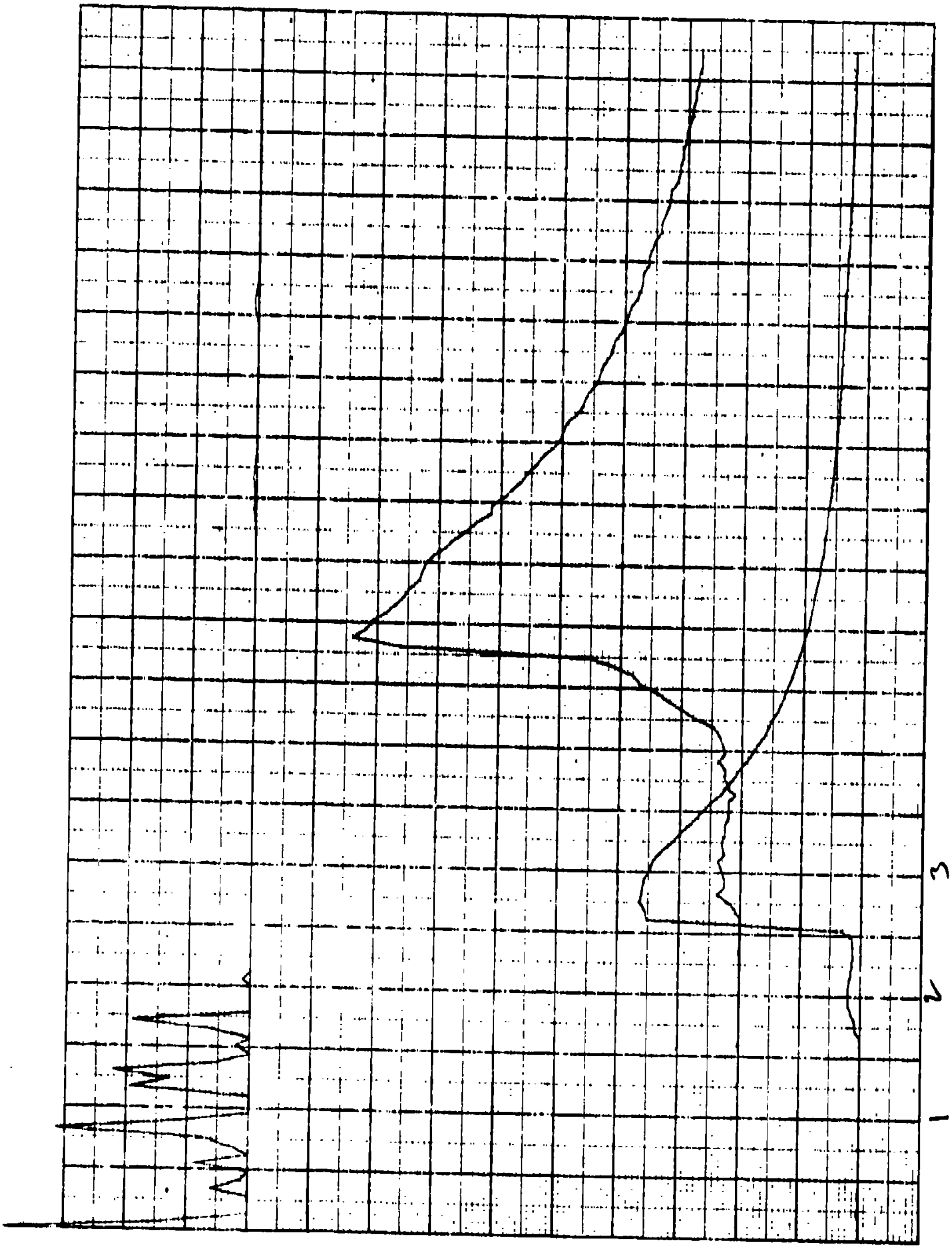
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TEST REPORT

SERIAL NO. 7

OBJECTIVE: To evaluate Celcon (Acetal) as a seal material candidate.

REFERENCE: S/N 5,6

BACKGROUND: Test series S/N 5 evaluated cartridges with brass seals that resulted in improved ballistic performance when compared to cartridges without seals. Similar results were observed in test series S/N 6. The brass seal was machined per Drawing No. SK 300520 and positioned on the end of the case. The case length was reduced to provide the desired crush up. Crush up less than 0.050 inch prevented case failure during chambering.

Celcon seals made to Drawing No. SK 300528 were machined from extruded round bar stock. The seals were not bonded to the cartridges.

Six rounds were assembled with:

Forward Charge	-	5479 Propellant
Aft Charge	-	8446-9 Propellant
Ignitor	-	TMS 300432
Retention	-	40/10 NC/Mylar
Primer	-	32 S&W
Case	-	Nylon 6/12, 43 percent glass
Seal	-	Celcon

BALLISTIC DATA:

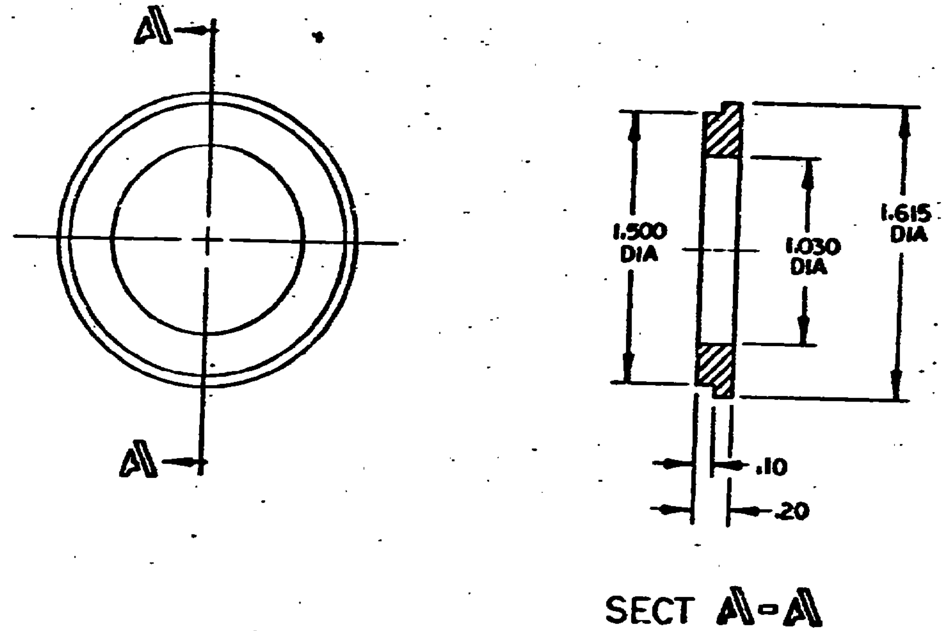
```
P1 MAX      P2 MAX      P3 MAX      VELOCITY     TIME
-------------------------------------------------------
ROUND NO--737
   32.7       -1.7        5.8          3156      5.18
   32.08       0          .83
LS1 TO LS2 3166
P3 TO LS2 3161
ROUND NO--738
   42.4       -.6         5.31         3491      5.32
   46.85       0          .4
LS1 TO LS2 3514
P3 TO LS2 3502
ROUND NO--739
   32.6       -.4         4.75         3156      5.18
   44.88       0          1.65
LS1 TO LS2 3135
P3 TO LS2 3146
ROUND NO--740
   35.3       -.2         4.81         3097      4.91
   45.34       0          2.62
LS1 TO LS2 3105
P3 TO LS2 3101
```

ROUND NO--741				
38.7	-.3	5.1	3315	5.12
45.83	0	1.32		
LS1 TO LS2 3331				
P3 TO LS2 3323				
ROUND NO--? 41				
742				
29.2	-.2	3.85	2830	5.05
42.69	0	3.36		
LS1 TO LS2 2806				
P3 TO LS2 2818				

DISCUSSION: Comparison of ballistic data recorded in this test series with S/N 5 and 6 indicates that the Celcon material was not equivalent to the metal seals. The action time was 5.2 milliseconds in this test compared to 4.2 milliseconds in S/N 5. The longer action time should have resulted in projectile velocities greater than the 3200 feet per second recorded. The average peak blowby pressure recorded was 6.25 Kpsi. This pressure indicates that the shot start cycle was in an over-ignition mode. This could be caused by a faulty seal, seal failure or the fact that the seals were not bonded to the case. The charred outer seal surface indicated excessive gas leakage between the seal and the case end. The seals were eroded away to varying degrees except for a narrow band that was welded to the case end. The remaining portion was welded by surface melting and pressure.

CONCLUSION: The Celcon material was not suitable as a seal in the configuration evaluated. Material erosion and ejection from the barrel were not desirable. The seal interface with the case was indicated to be important from a gas path and over-ignition shot start sequence.

Additional tests are recommended in an alternate seal design configuration.



SEAL
25MM PLASTIC CASE

25MM PLASTIC CASE
AMMUNITION DEVELOPMENT

S/N: 7
DATE: 24 JUNE 76
ENGR: Cary
AMMO: Richardson

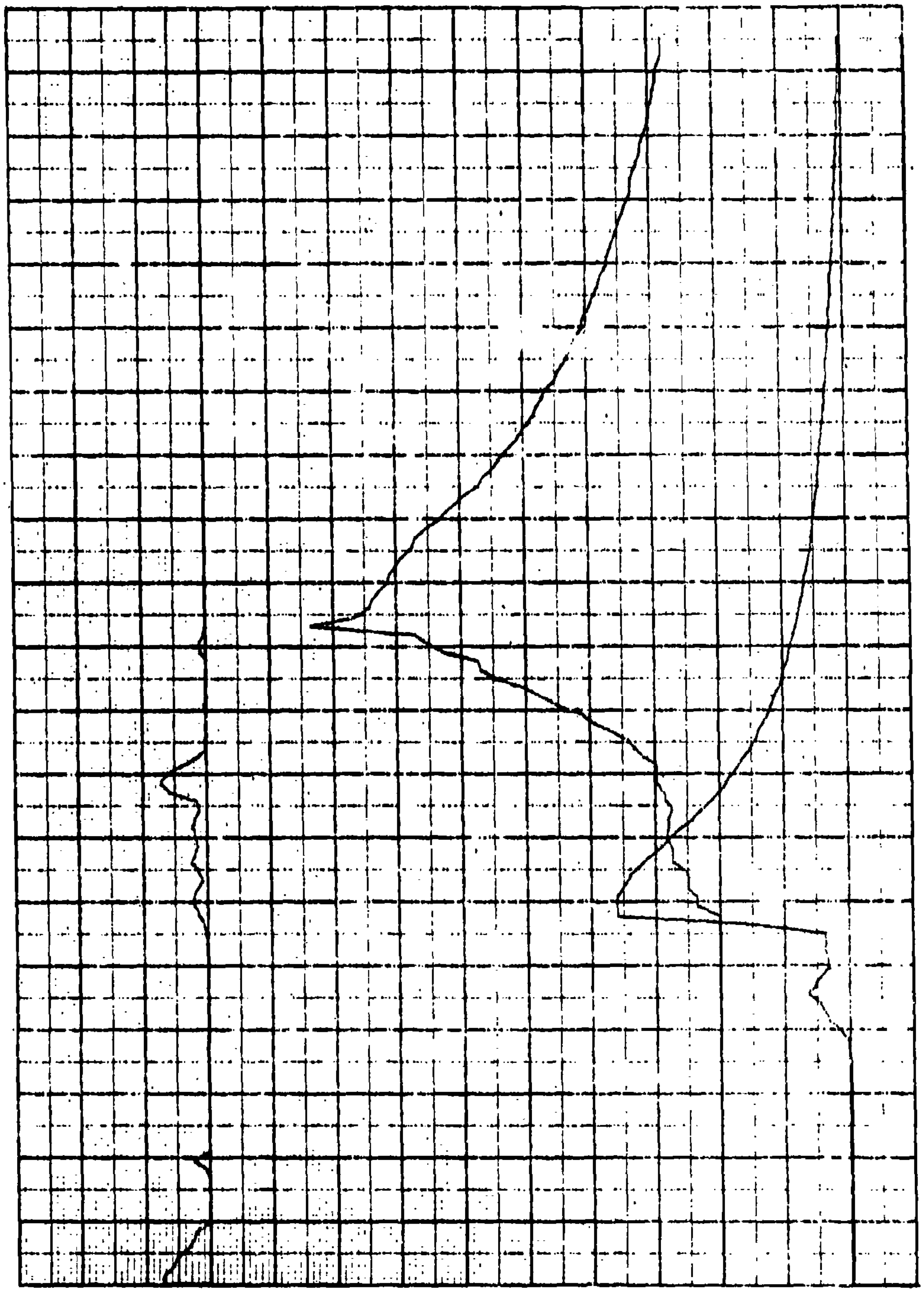
OBJECTIVE: To Evaluate Celcon (Acetal) As A Seal Candidate

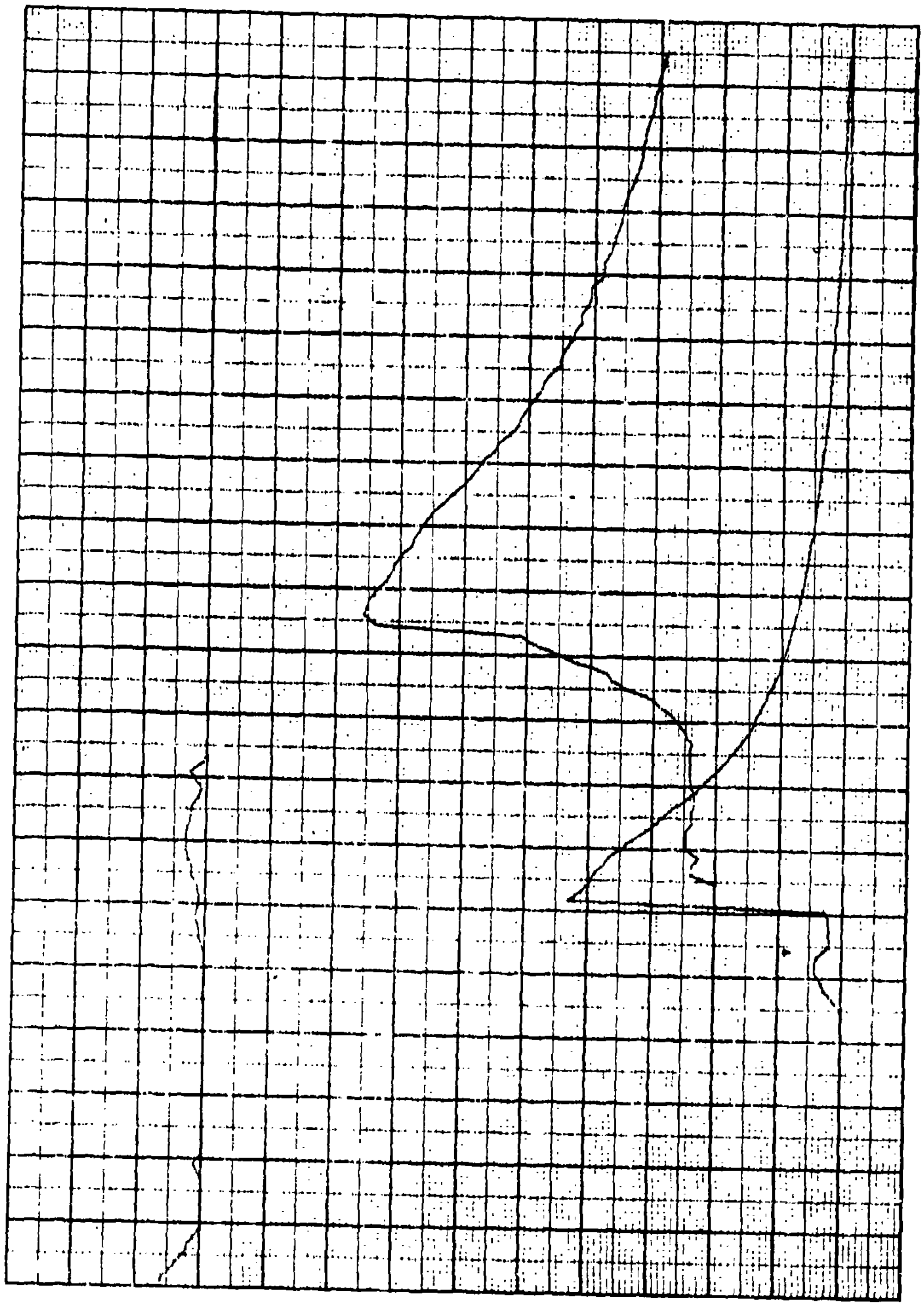
Test Fixture: IITRI, UNIVERSAL, RIA.
Cartridge Case: Dwg. No. SK 300460, Rev. ____, Mat'l 6/12 Nylon $3% Glass
Dwg. No. ______, Rev. ____, Mat'l ______.
Projectile: Dwg. No. 300347, Rev. A, Plastic Band, 3000 Grain.
Primer: Type ______, Lot No. ______, No. ______.
Flash Tube: 3256W, 38 Special, ______. Loctite 15150
Projectile Retention: 10 Mil NC, 10 Mil Mylar, ____ Mil
Ignitor: TMS 300432, Seals: Celcon Dwg No. SK300520
Propellant: Fwd Charge 5079, Lot No. 69-616.
Aft Charge 8446-9, Lot No. 69-607.
Insert —, Lot No. ______.

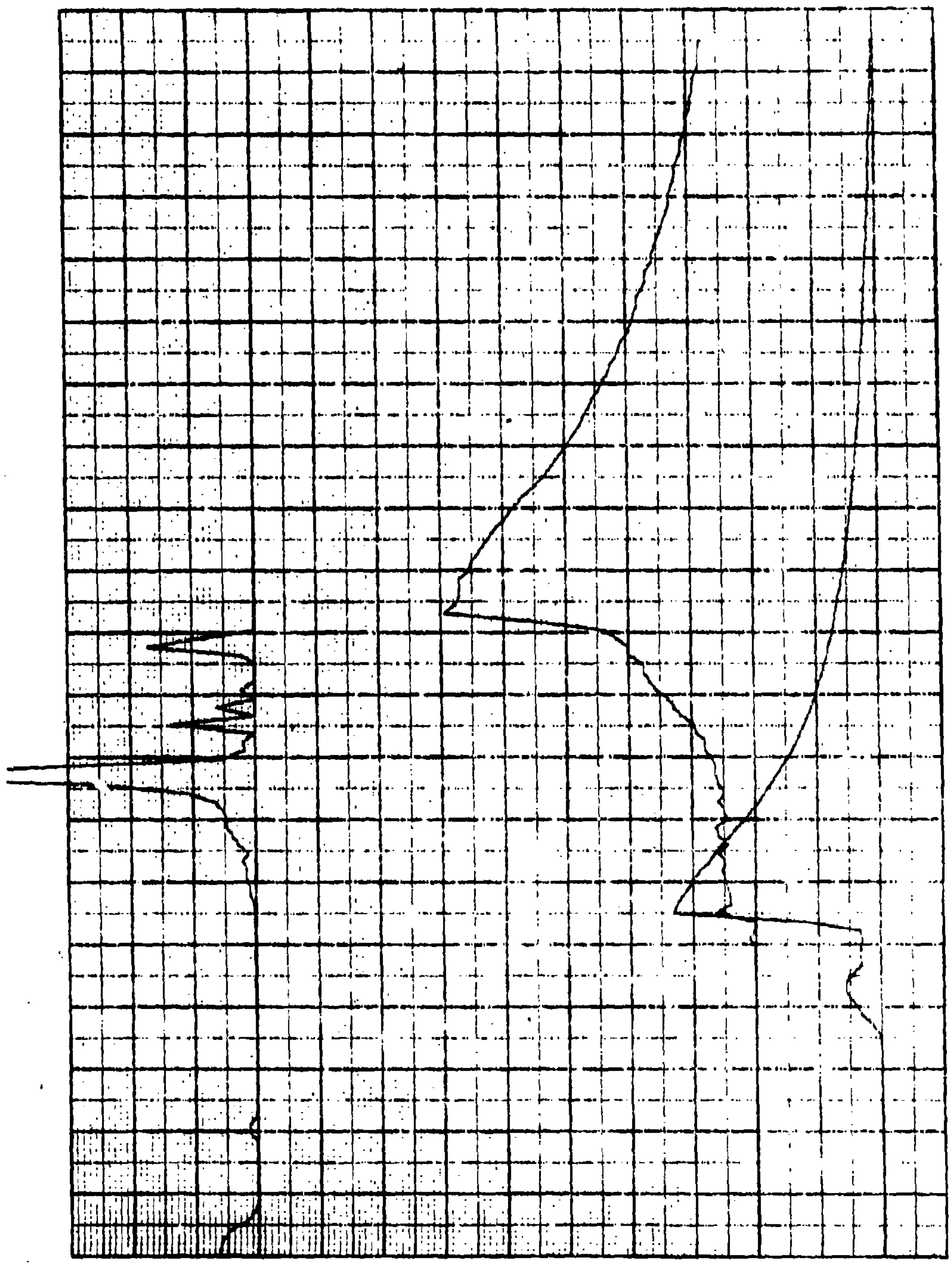
REMARKS: Round Length 6.075"/6.085" (0.020"/0.030" Crush)

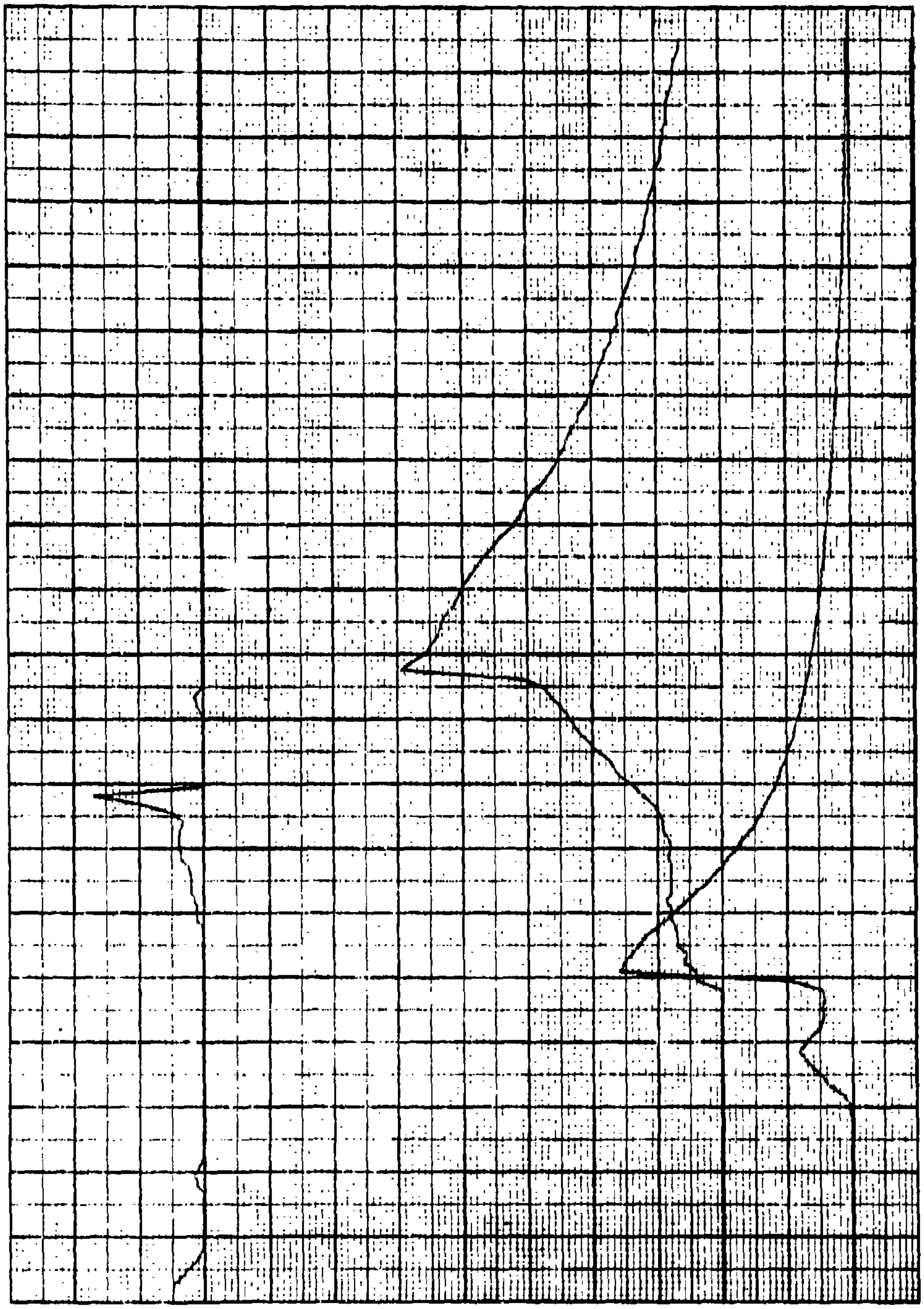
ROUND NO.	PROPELLANT WT (GRAMS)			TOTAL PROP. WT	IGNITOR WT
	FWD	AFT	INSERT	(GRAMS)	(GRAMS)
37	93.3	44.7	—	138.0	0.15
38	93.5	47.7	—	141.2	0.15
39	93.6	44.5	—	138.1	0.15
40	93.9	44.7	—	138.6	0.15
41	93.9	44.4	—	138.4	0.15
42	93.3	44.5	—	137.7	0.15

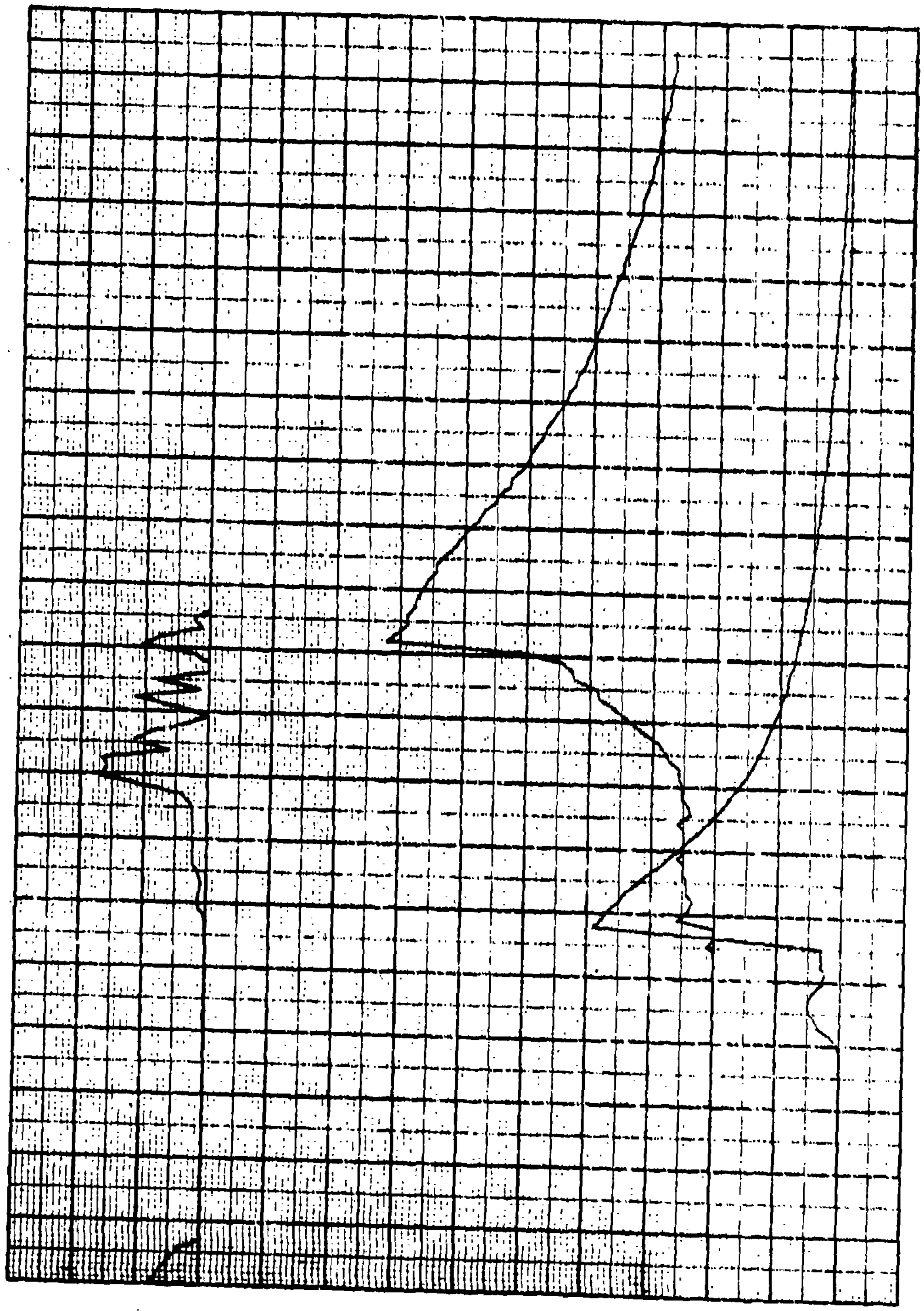
FORM NO. SG-555-81

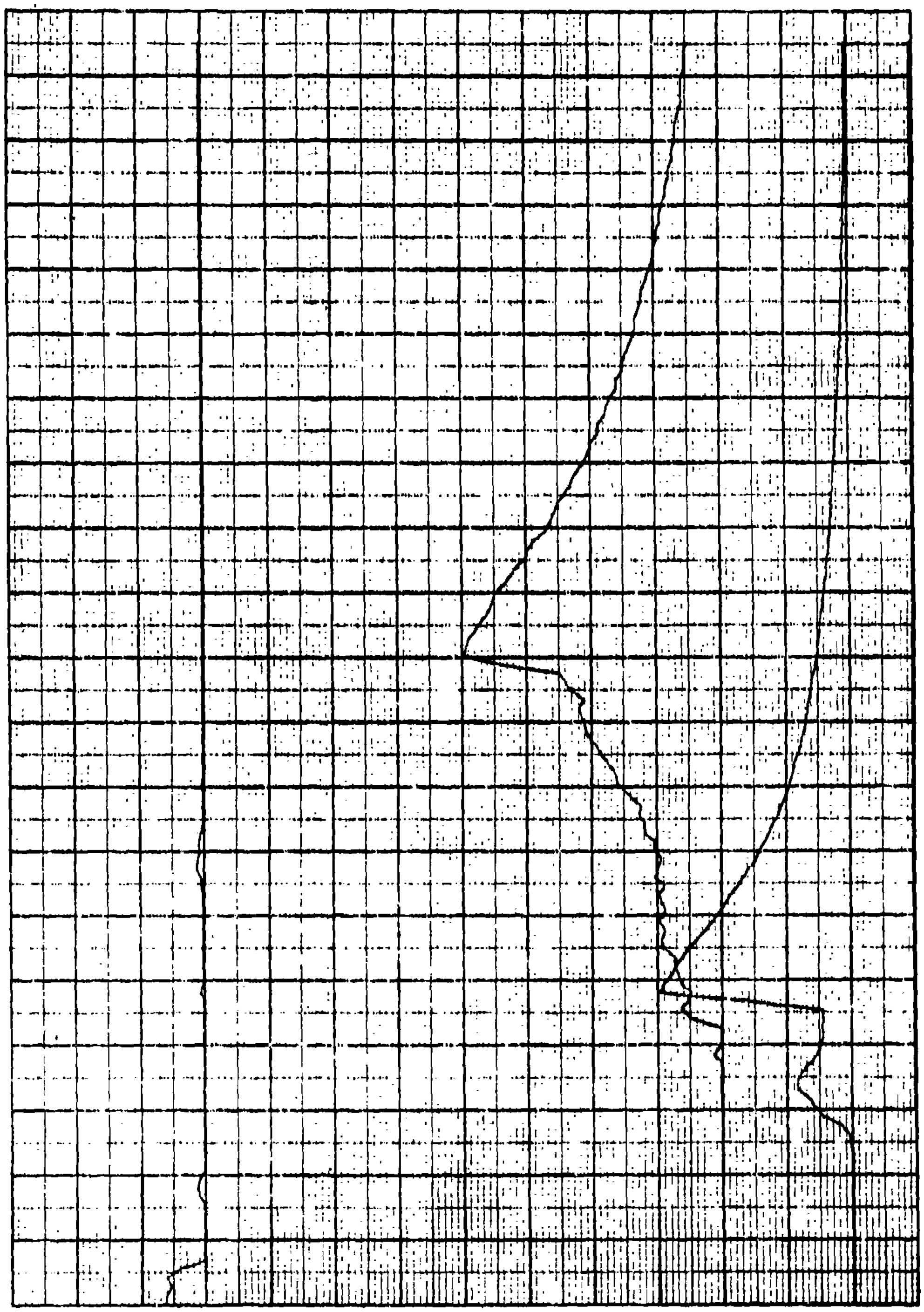












TEST REPORT

SERIAL NO. 8

OBJECTIVE: To observe the effect of the interference seal concept on ballistic performance.

REFERENCE: S/N 5.

BACKGROUND: Favorable ballistic performance was recorded in S/N 5. This was interpreted to be the result of an interference between the brass seal and the projectile in the shot start cycle. The projectile was forced to decelerate as it obturated the barrel. A decrease in the rate of change of free volume improves the propellant ignition process by increasing local pressure. Propellant blowby should be reduced because of the reduced flow area caused by the interference of the seal. The brass seal deformation indicated that the projectile was probably damaged during the impact. To minimize the damage and maintain the desirable shot start properties, it was determined to evaluate plastic materials to replace the brass seal.

Celcon was selected as the first candidate for a nonmetal seal. The seal was configurated similar to the brass as shown in SK300523. The inside diameter was reduced to reflect different degrees of interference.

Twelve rounds were assembled with:

Forward Charge	-	5440 propellant
Aft Charge	-	8446-9 propellant
Ignitor	-	TMS300432, 300439
Retention	-	40/10 - NC/Mylar
Primer	-	32 S&W
Case	-	Nylon 6/12, 43 percent glass
Seal	-	Celcon

BALLISTIC DATA:

P1 MAX	P2 MAX	P3 MAX	VELOCITY	TIME	
ROUND NO--743					
37.3	0	4.74	3068	4.98	Ignitor:
45.29	0	2.96			TMS 300432
LS1 TO LS2 3075					
P3 TO LS2 3071					
ROUND NO--746					
30.3	-.2	3.93	2905	5.8	
46.59	0	5.36			
LS1 TO LS2 2499					
P3 TO LS2 2690					

```
                    ROUND NO--749
                       39.2        .1          4.58        3097     5.18
                       49.17       0           4.51
                    LS1 TO LS2 3046
                    P3 TO LS2 3071
                    ROUND NO--752
BALLISTIC              45.7        0           6.06        3646     6.06
DATA:                  58.23       0           1.18
                    LS1 TO LS2 3675
                    P3 TO LS2 3660
```

Ignitor: TMS 300439

```
P1 MAX       P2 MAX      P3 MAX     VELOCITY      TIME
-------------------------------------------------------
ROUND NO--744
   29.9        -1.7        5.3       2900 Est     5.6
   31.51        0          2.41
LS1 TO LS2 44
P3 TO LS2 0
ROUND NO--745
   38.2        -.5         6.46        9999       53.25
   19.76        0          0
LS1 TO LS2 43
P3 TO LS2 0
ROUND NO--747
   24.1        -.3         5.41        2985       6.01
   42.58        0          5.53
LS1 TO LS2 2191
P3 TO LS2 2503
ROUND NO--750
   44.6        -.1         7.61        3906       14.94
   53.12        0          0
LS1 TO LS2 3899
P3 TO LS2 3902
ROUND NO--748
   19.7        -.1         3.55        4[illegible]4  9.92
   37.83        0          5.92
LS1 TO LS2 1616
P3 TO LS2 2428        No correlation
ROUND NO--751
   53.7         0          7.1         3860       12.53
   52.33       .08         0
LS1 TO LS2 3852
P3 TO LS2 3856
ROUND NO--753
   39.1         0          6.33        3097       5.67
   50.99       .26         5.77
LS1 TO LS2 2734
P3 TO LS2 2906
ROUND NO--754
   36.7        .2          6.24        3068       6.01
   50.39       .51         4.14
LS1 TO LS2 3075
P3 TO LS2 3071
```

DISCUSSION: The ballistic results were separated into four seal configurations with inside diameters of 0.985, 0.870, 0.750 and 0.625 inch. Each group was evaluated with two TMS ignitors 300432 and 300439.

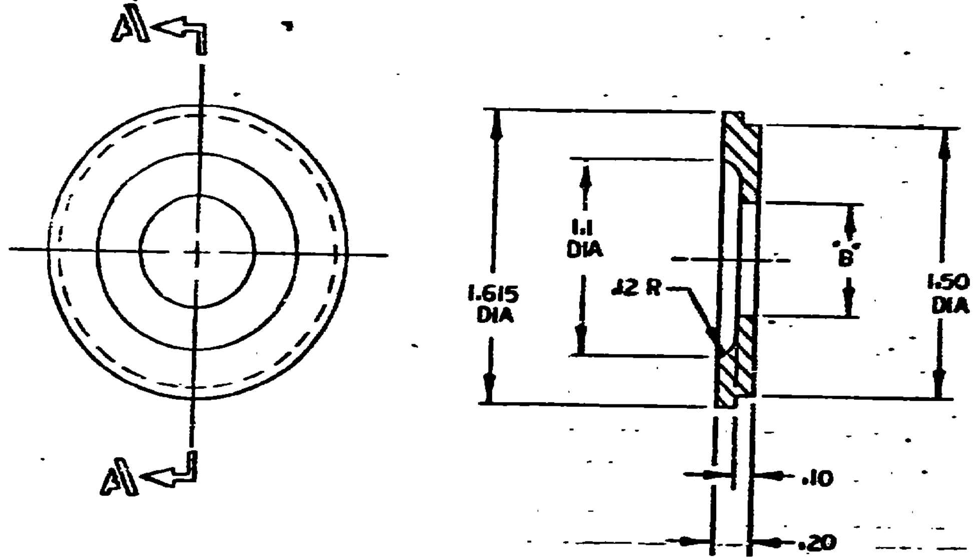
The most significant effect on ballistic performance was indicated with the small inside diameter seals. The velocity improved to a greater value with the 432 ignitor and the 0.625 inch seal aperture. The limited number of tests were not sufficient to confirm the results.

The cartridge cases and seals were examined. All but one case was charred on the exterior surface indicating seal leakage. The leak was anticipated because no attempt was made to bond the seal to the case. Oblong portions of the seal were recovered down range. Examination of these pieces indicated that the seal obturated with the barrel but was ejected from the barrel early in the ballistic cycle. The portion of the seals that remained with the cases were approximately 0.060 inch thick and these were thermally welded to the case by the combustion gases.

The origin of the case base crack has been identified. The cases that have failed at the base have been with glass contents greater than 33 percent and in cartridges evaluated with TMS300432 ignitor. Similar tests with TMS300439 ignitor have not caused case failure. The 432 is more brizant than the 439. The crack originates at the ignitor/case interface. It is the result of the rapid expansion of the S&W brass caused by the burning ignitor. The crack can be eliminated by removing a portion of the ignitor support in the case or changing the interface with the brass ignitor.

CONCLUSION: The interference seal concept was feasible and indicates that velocity improvements without sacrificing the other ballistic properties was possible. Celcon was not a satisfactory material candidate because of the difficulty in providing a satisfactory bond with the case. The tests should be repeated with nylon seals that are bonded to the case. A seal design modification should be incorporated to allow for material displacement without material loss.

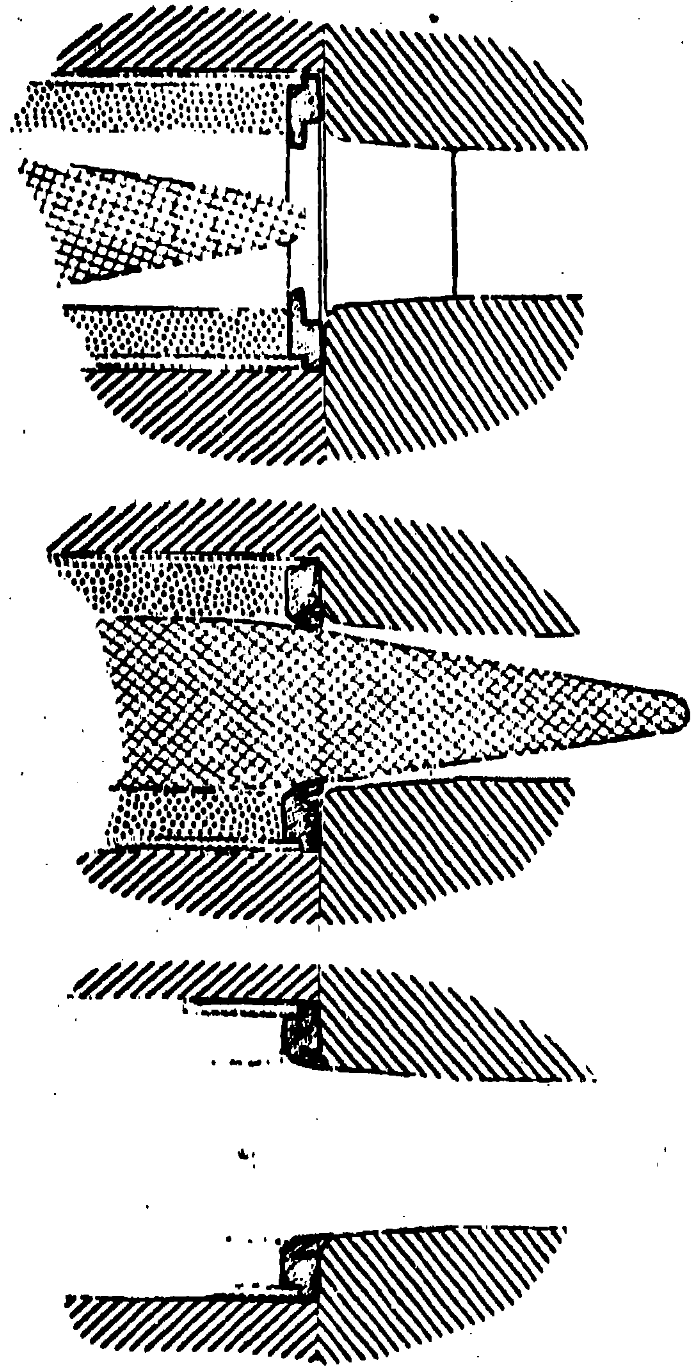
The cause of case failure at the base has been identified and can be corrected.



SECT A-A

NO.	"B" DIA
-1	.625
-2	.750
-3	.870
-4	.985
-5	1.100

SEAL
25MM PLASTIC CASE



INTERFERENCE SEAL CONCEPT

25MM PLASTIC CASE
AMMUNITION DEVELOPMENT

S/N: 8
DATE: 24 JUNE 79
ENGR: CARY
AMMO: RICHARDSON

OBJECTIVE: TO OBSERVE THE INTERFERENCE SEAL EFFECT ON BALLISTIC PERFORMANCE

Test Fixture: IITRI, UNIVERSAL, RIA.
Cartridge Case: Dwg. No. SK 300460, Rev.____, Mat'l NYLON 6/12, 43 Percent glass
Dwg. No. ____, Rev.____, Mat'l ____.
Projectile: Dwg. No. 300347, Rev. A, Plastic Band, 3000 Grain.
Primer: Type ____, Lot No. ____, No. ____.
Flash Tube: (1254V) 38 Special, ____.
Projectile Retention: 40 Mil NC, 10 Mil Mylar, LOCTITE 15/58 Mil
Ignitor: THS 432 & 439, Seals: CELCON SK300523-1,-2,-3,-4.
Propellant: Fwd Charge 5440, Lot No. ____.
Aft Charge 8946-9, Lot No. 89-617.
Insert ——, Lot No. ____.

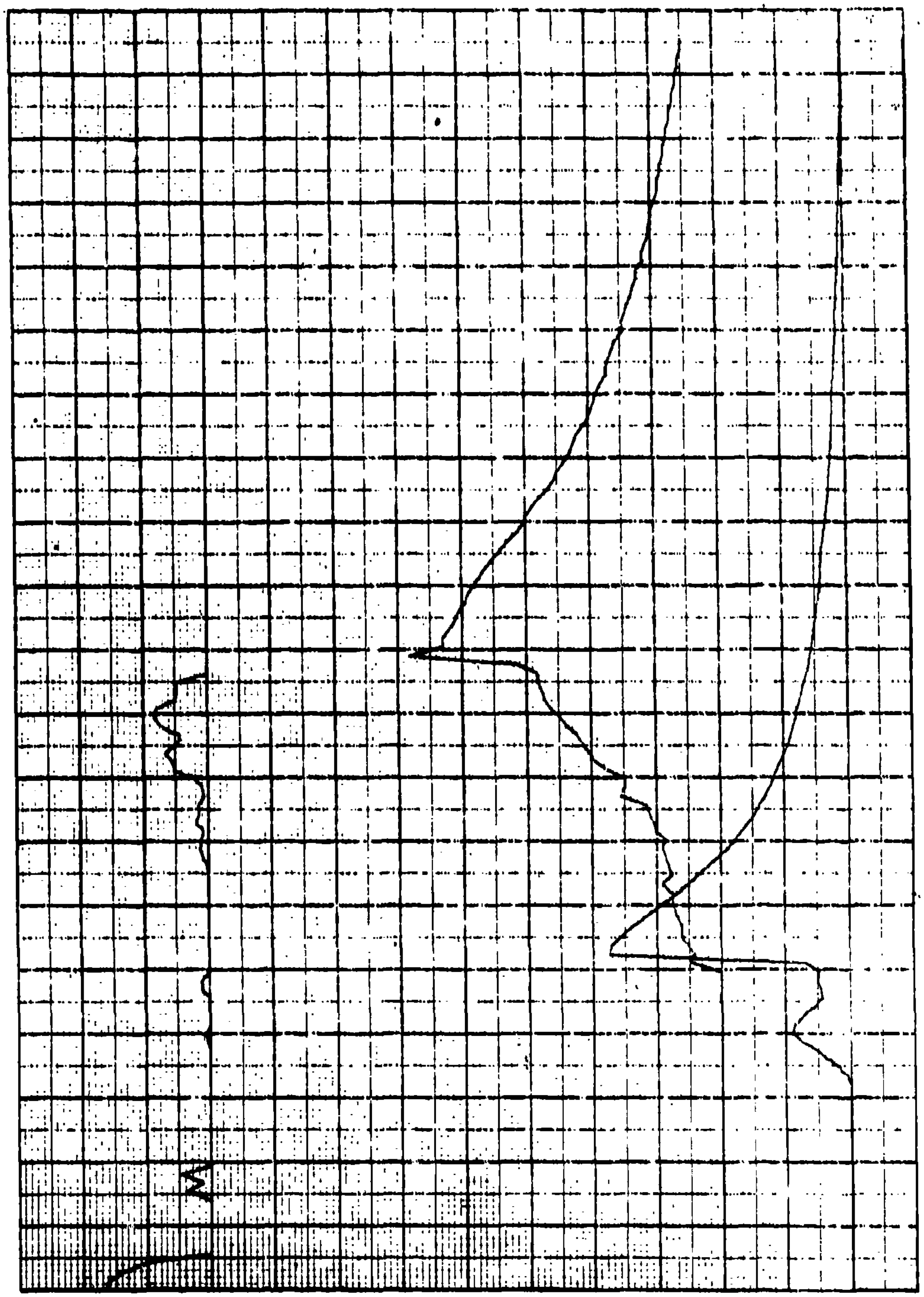
REMARKS: STAGED IGNITION ATTEMPTED WITH GELATIN CAPSULE CONTAINING PORTION OF IGNITOR. *

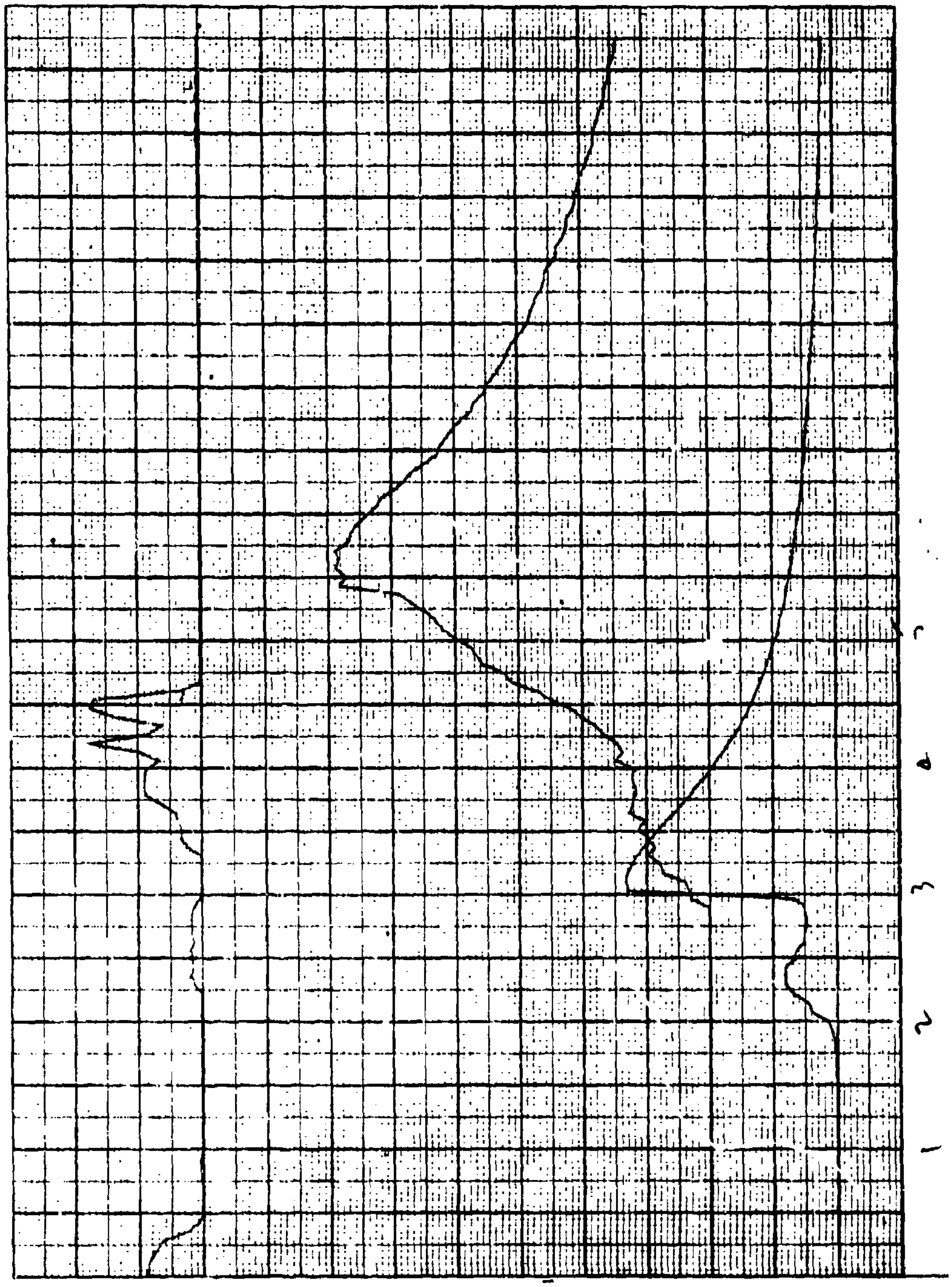
CARTRIDGE LENGTH 6.075/6.085 (0.020/0.030" CRUSH UP)

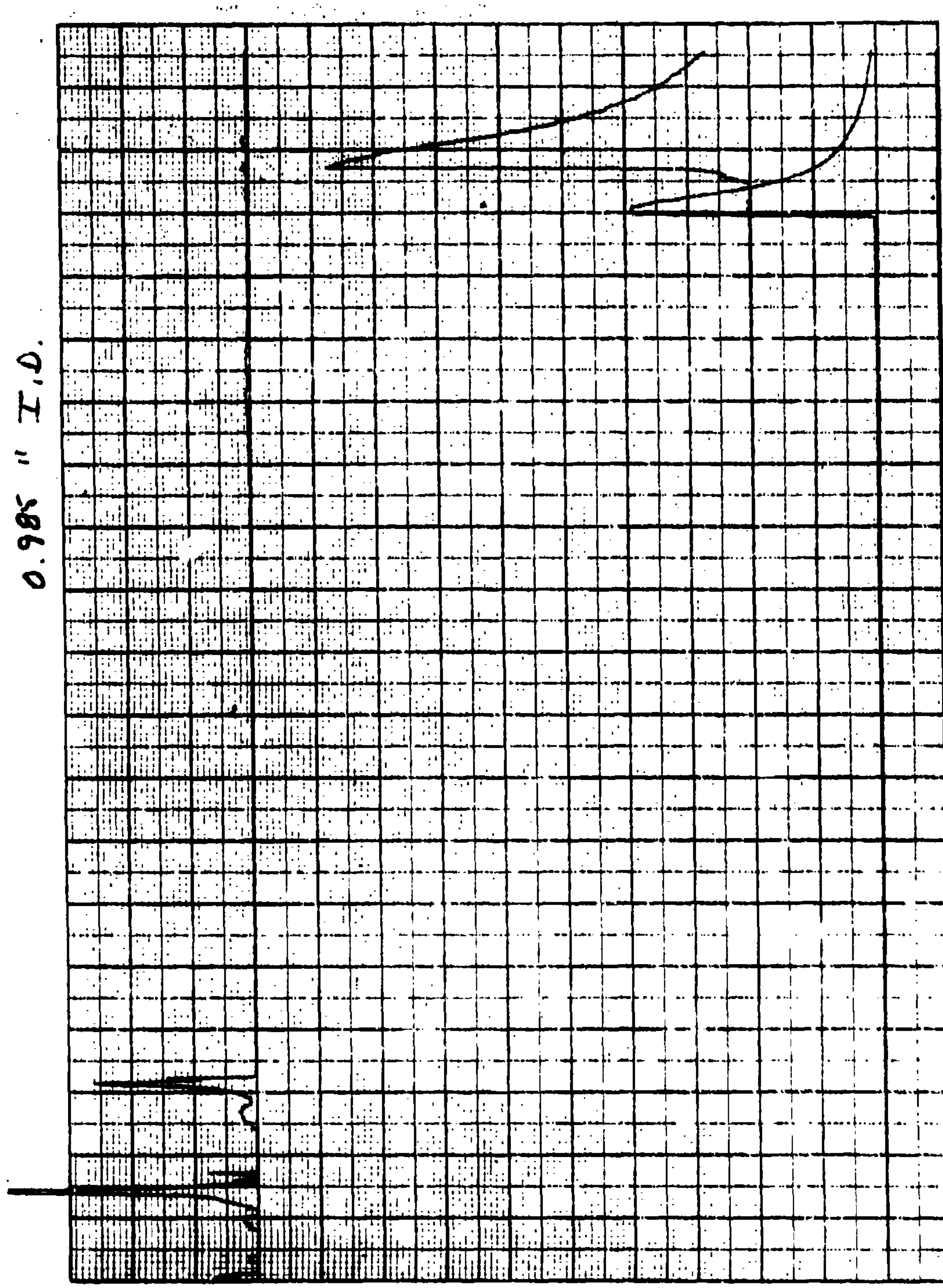
SEAL I.D.	ROUND NO.	PROPELLANT WT (GRAMS) FWD	AFT	INSERT	TOTAL PROP. WT (GRAMS)	IGNITOR WT (GRAMS)
0.985	43 (2)	92.7	44.5	—	137.2	0.15 (432)
	44	91.3	44.5	—	135.8	0.3 (439)
	45	85.0	44.4	—	129.4	0.2 (439) } 0.15 FWD BAG *
0.870	46	86.3	44.7	—	131.0	0.15 (432)
	47	84.4	44.5	—	128.9	0.25 (439) 0.15 GELATIN BAG *
	48	87.7	44.6	—	132.3	0.25 (439) *
0.750	49	92.2	44.8	—	137.0	0.15 (432)
	50	88.3	44.5	—	132.8	0.25 (439)
	51	84.5	44.7	—	129.2	0.25 (439)
0.625	52	85.9	44.7	—	130.6	0.15 (432)
	53	92.3	44.8	—	137.1	0.25 (439)
	54	88.0 (1)	44.6	—	132.6	0.25+ (439)

(1) 5479 PROPELLANT
(2) SEAL I.D. = 1.00"

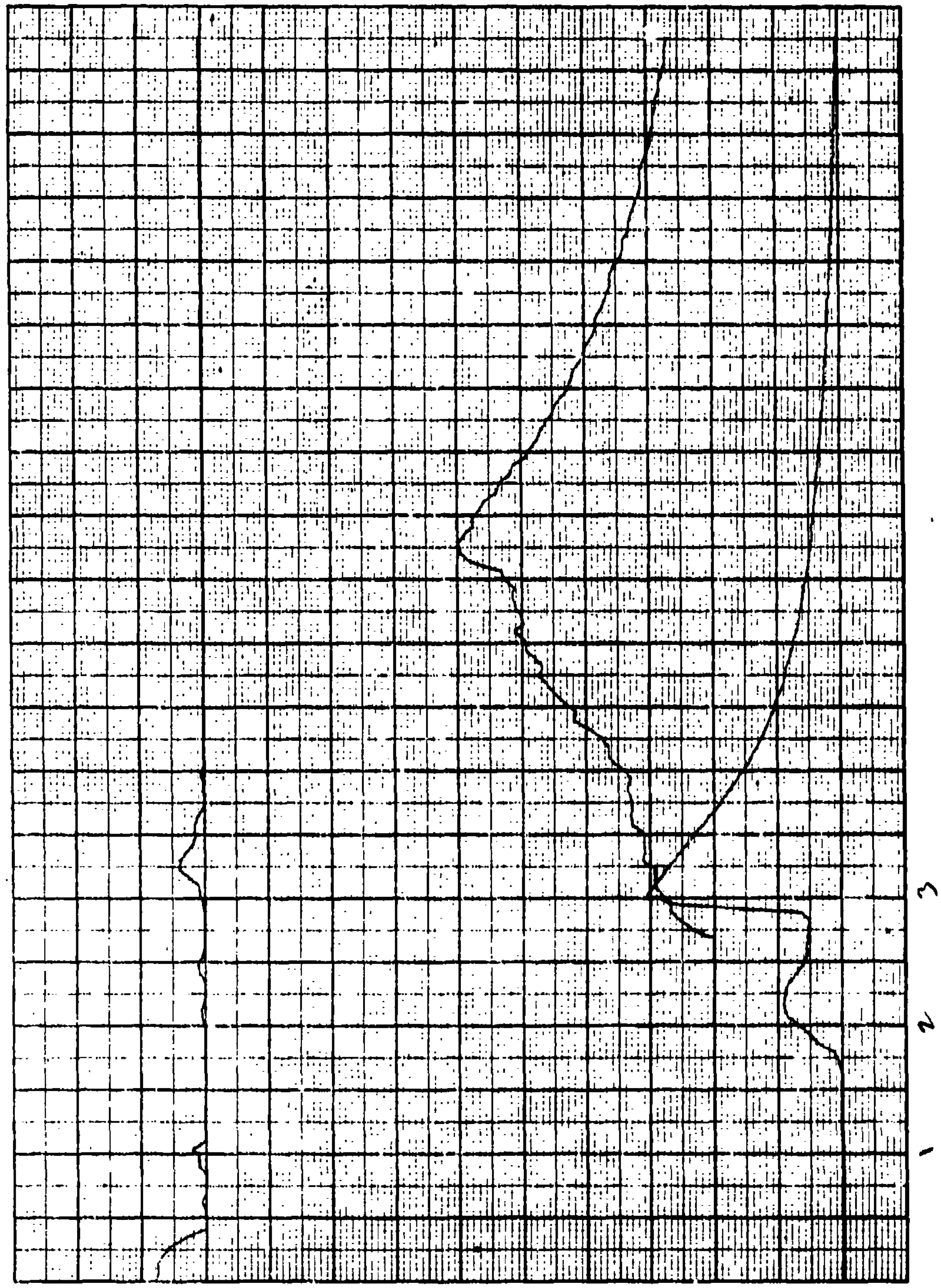
FORM NO. SG-555-81

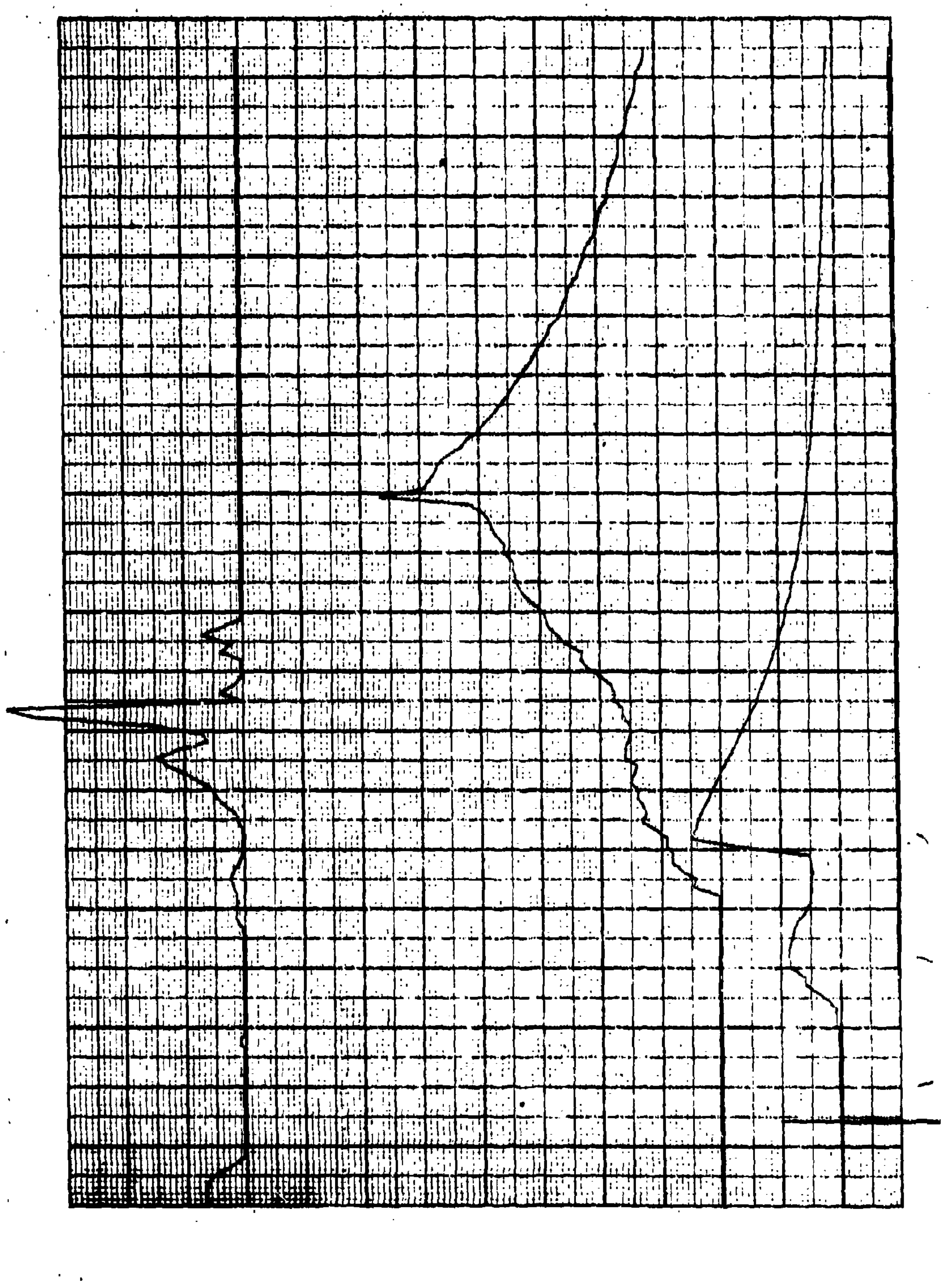


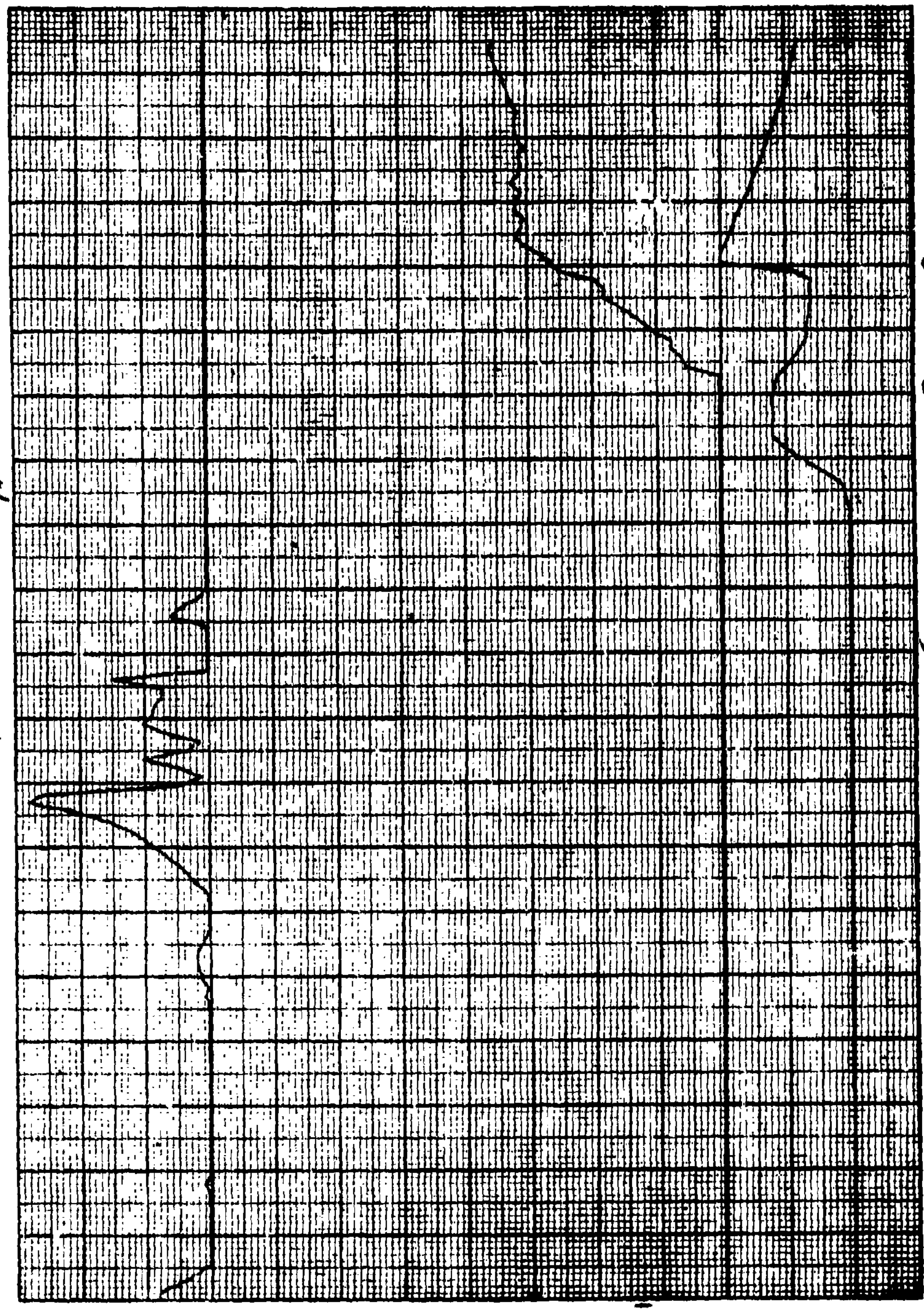



0.985 " I.D.

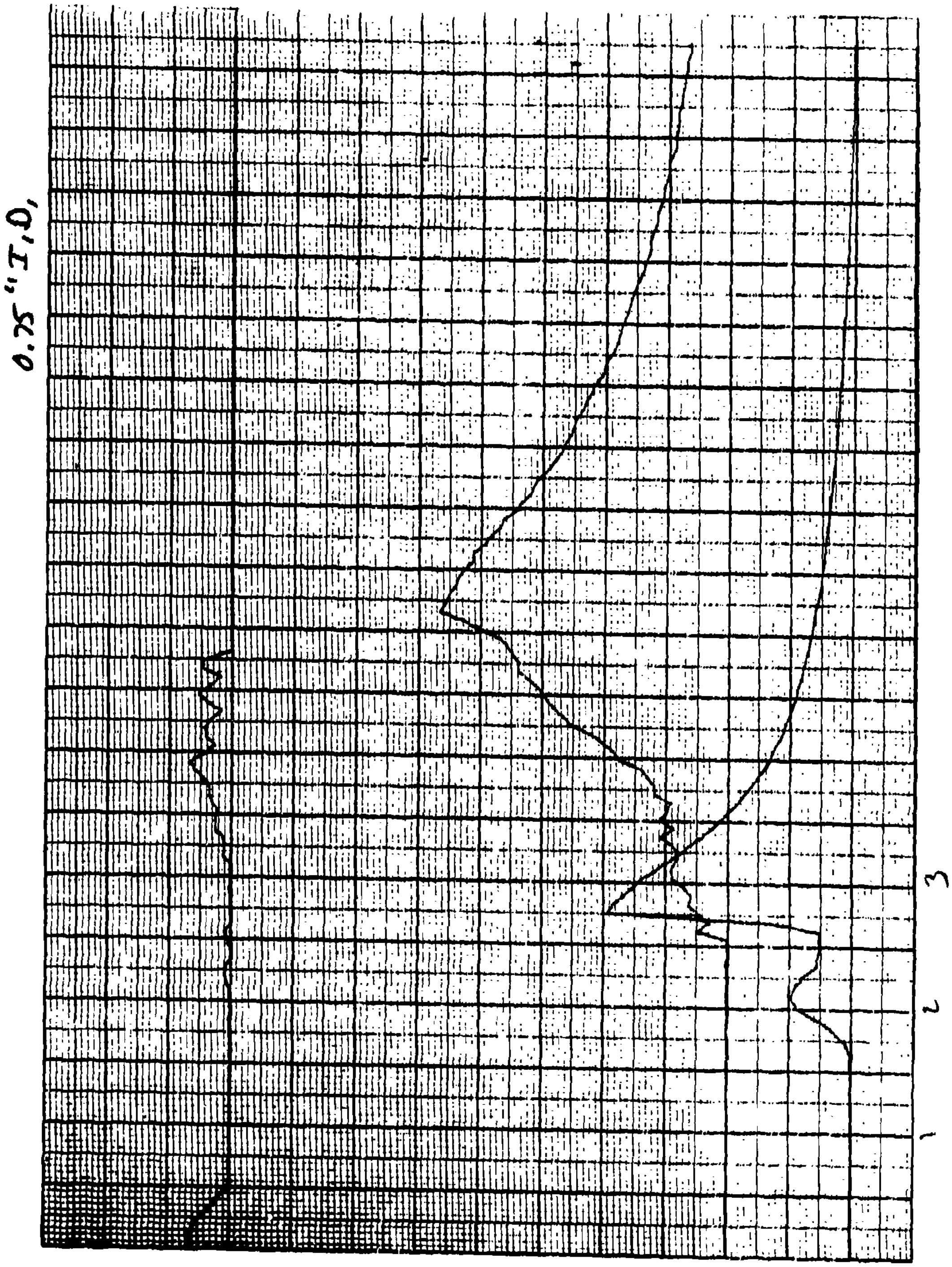
0.870 " I.D.

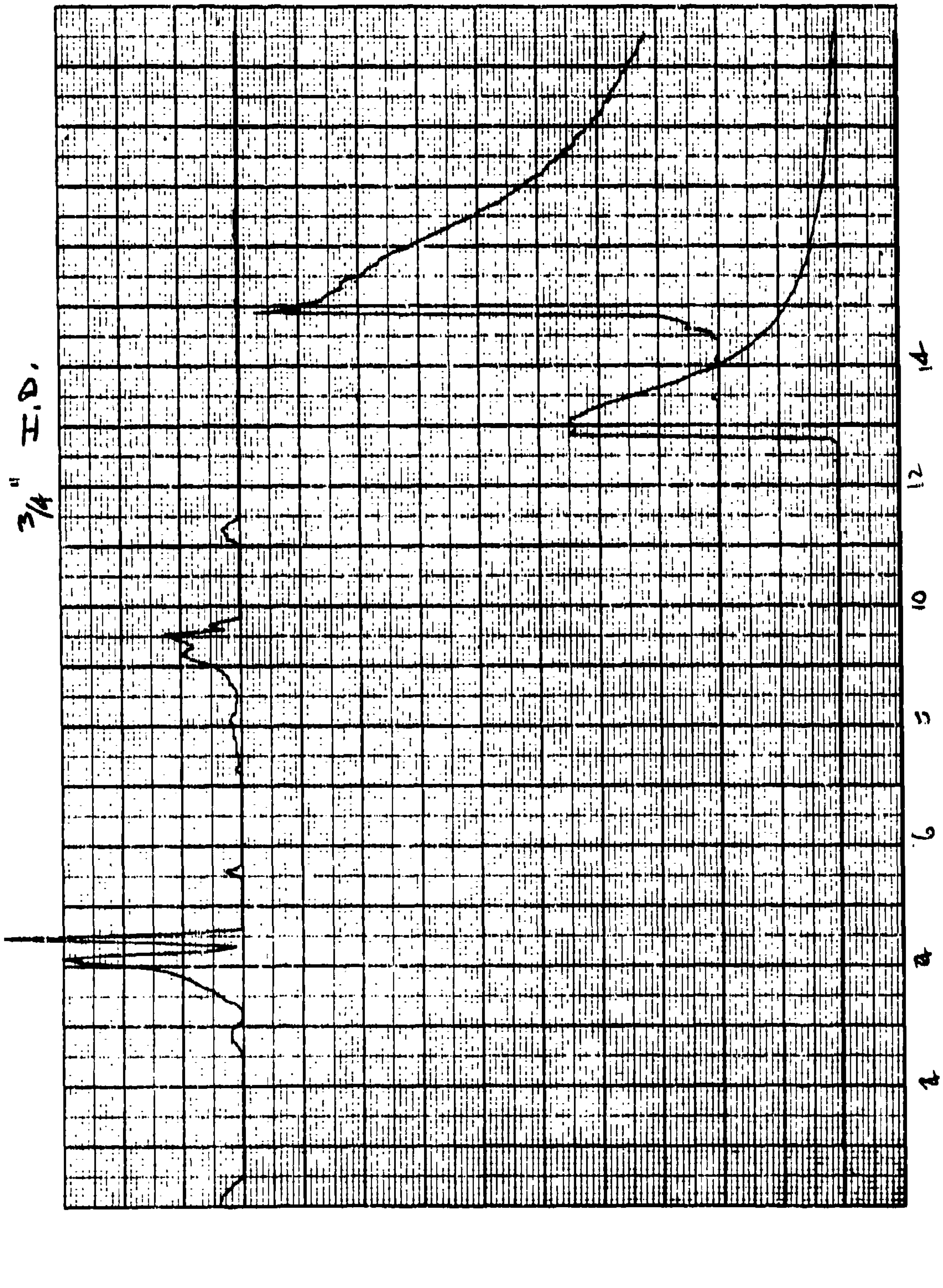


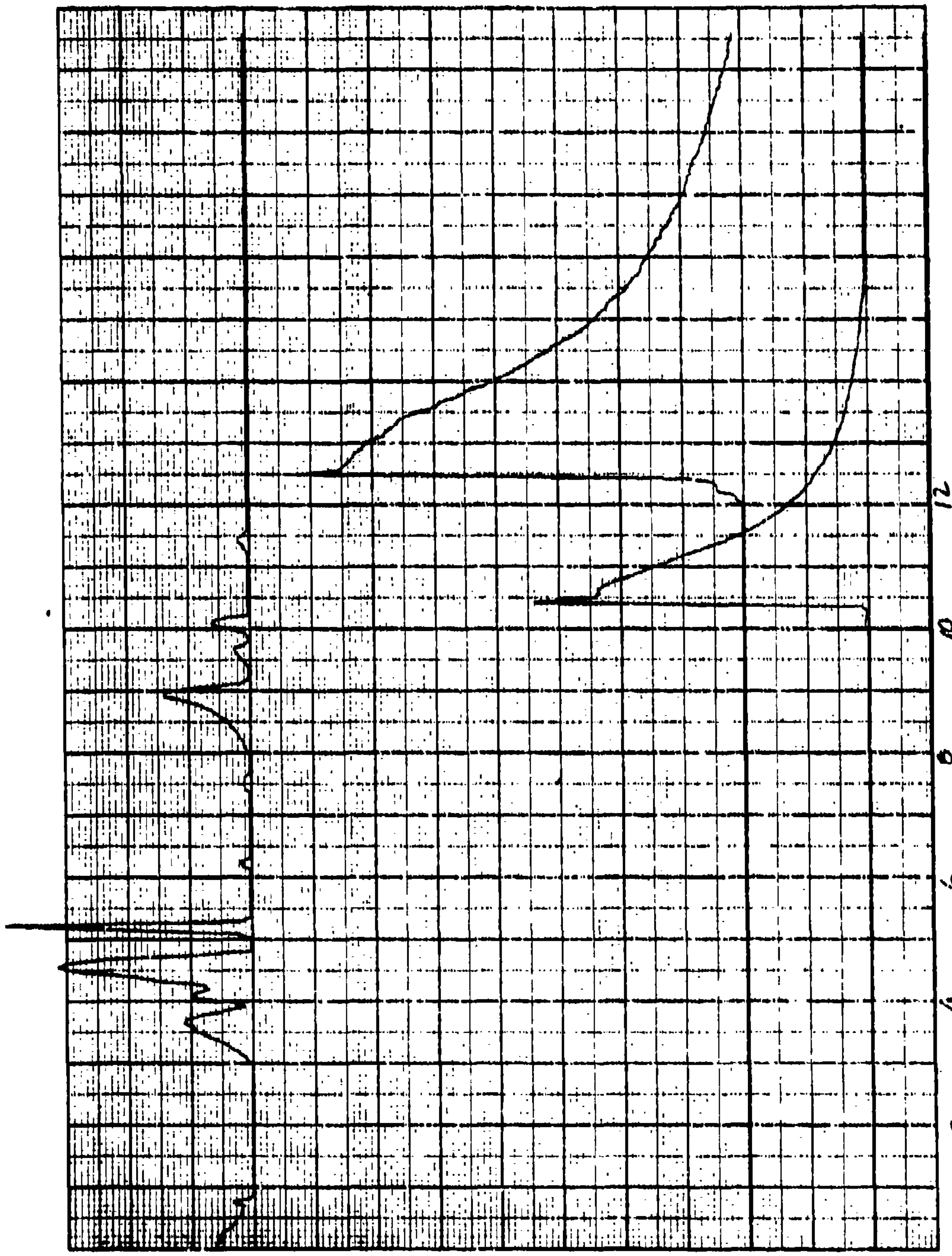




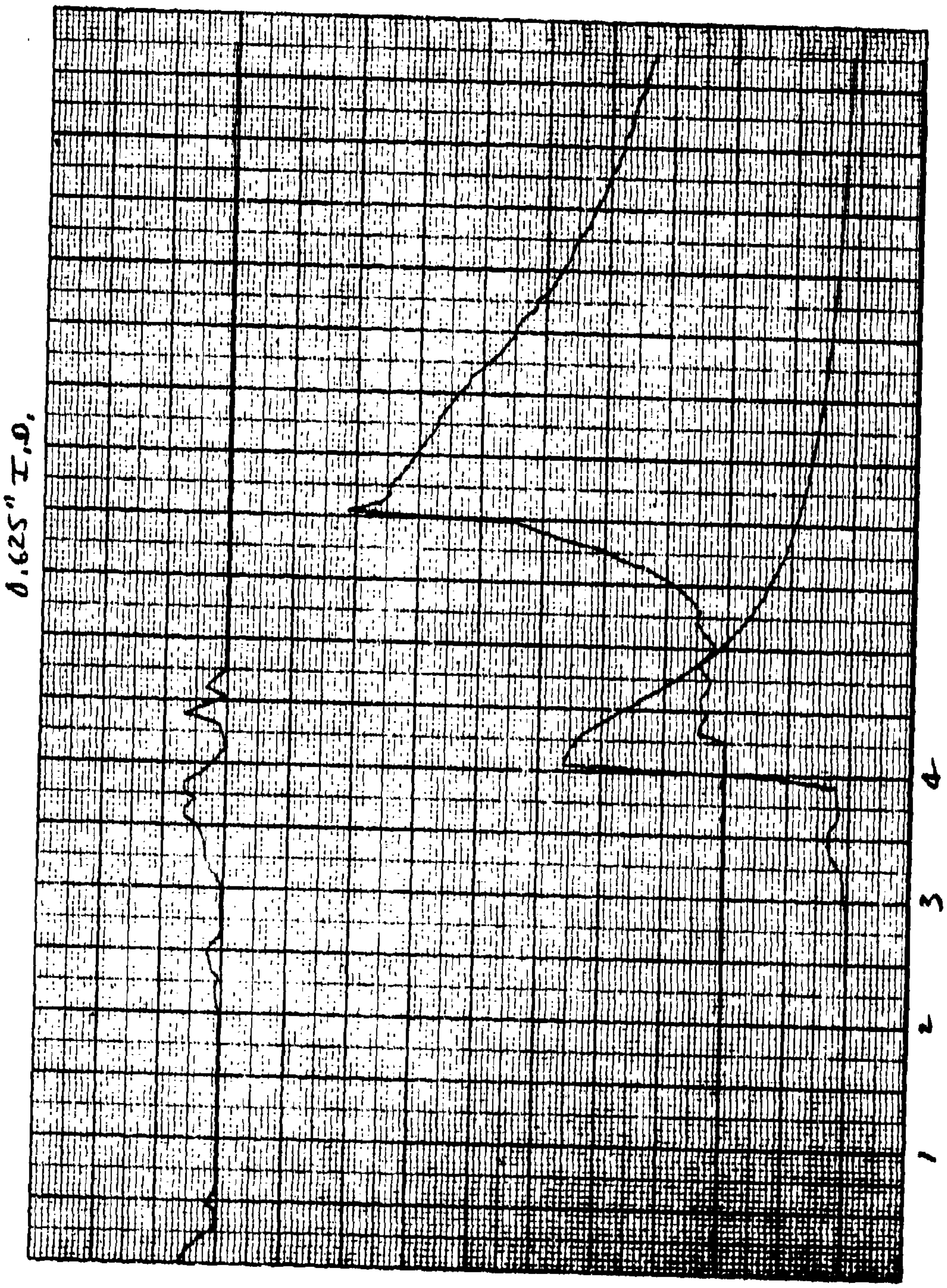
7/8" I.D.

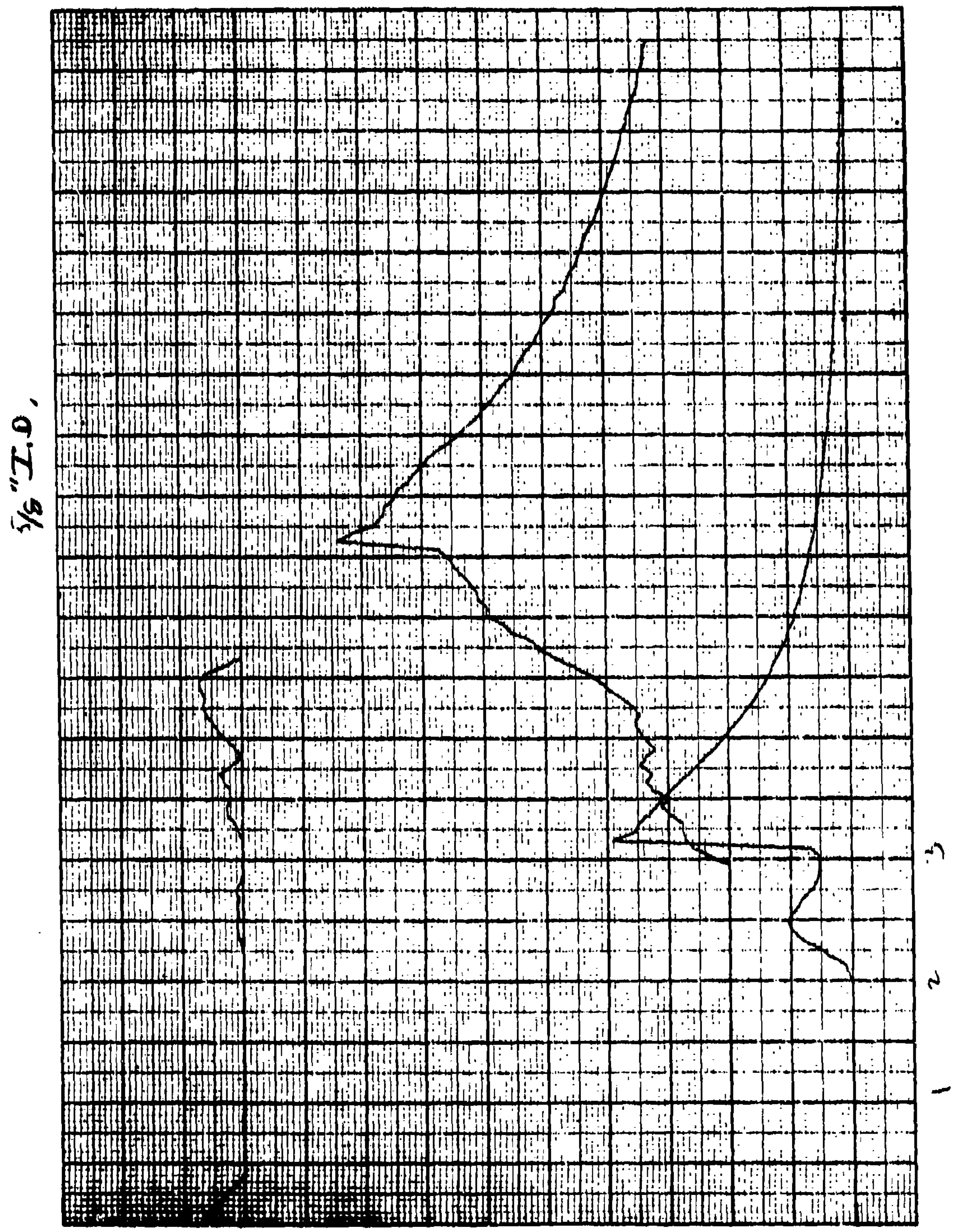

0.25", I.D.
1
2
3

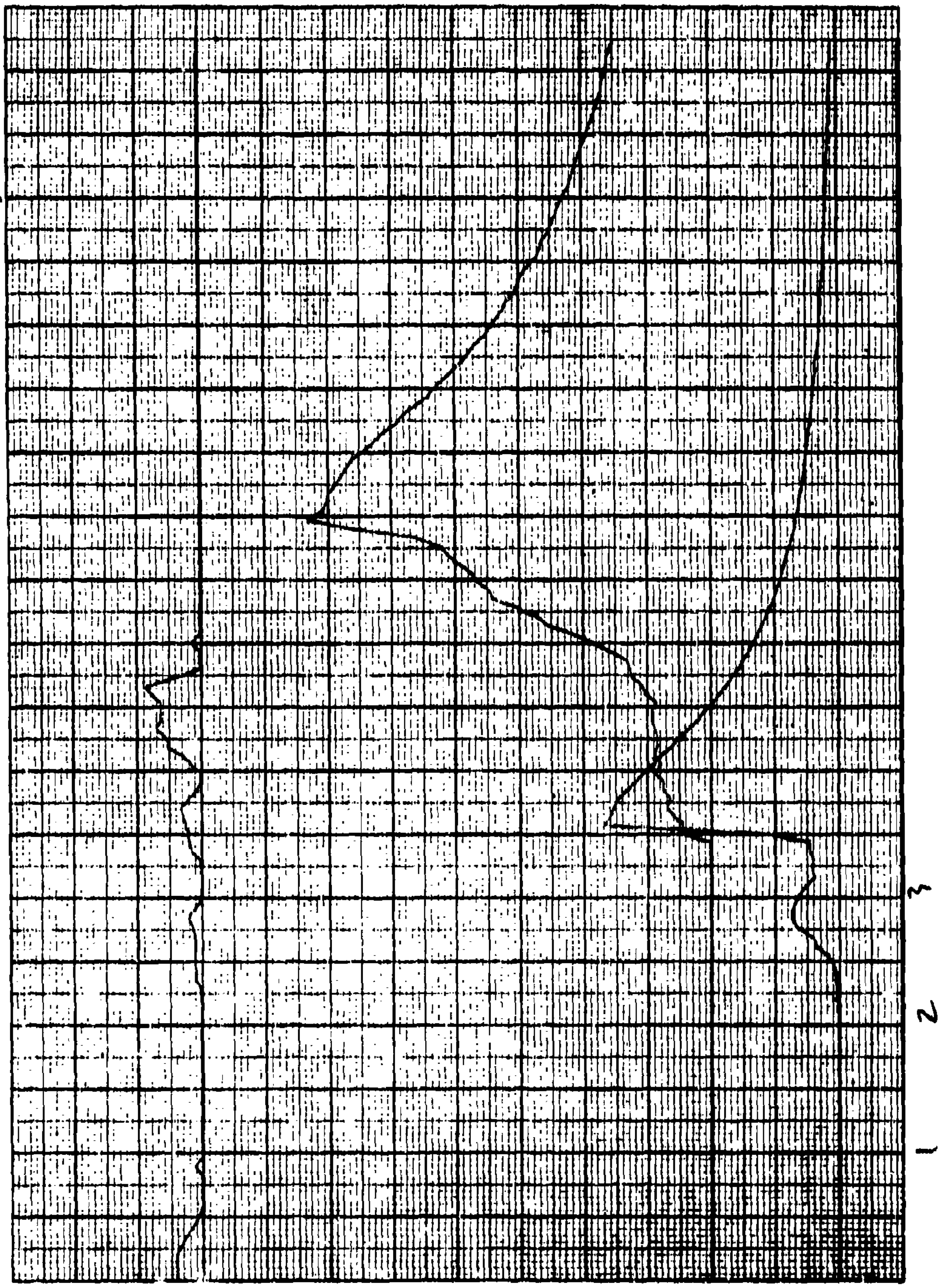

3/4" H.D.
2
4
6
8
10
12
14



2
4
6
8
10
12

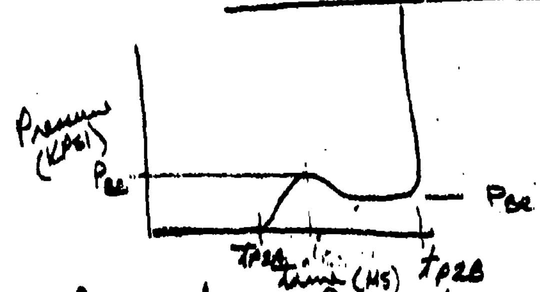

0.625" I.D.
1
2
3
4




1
2
3

SHOT START DEVELOPMENT

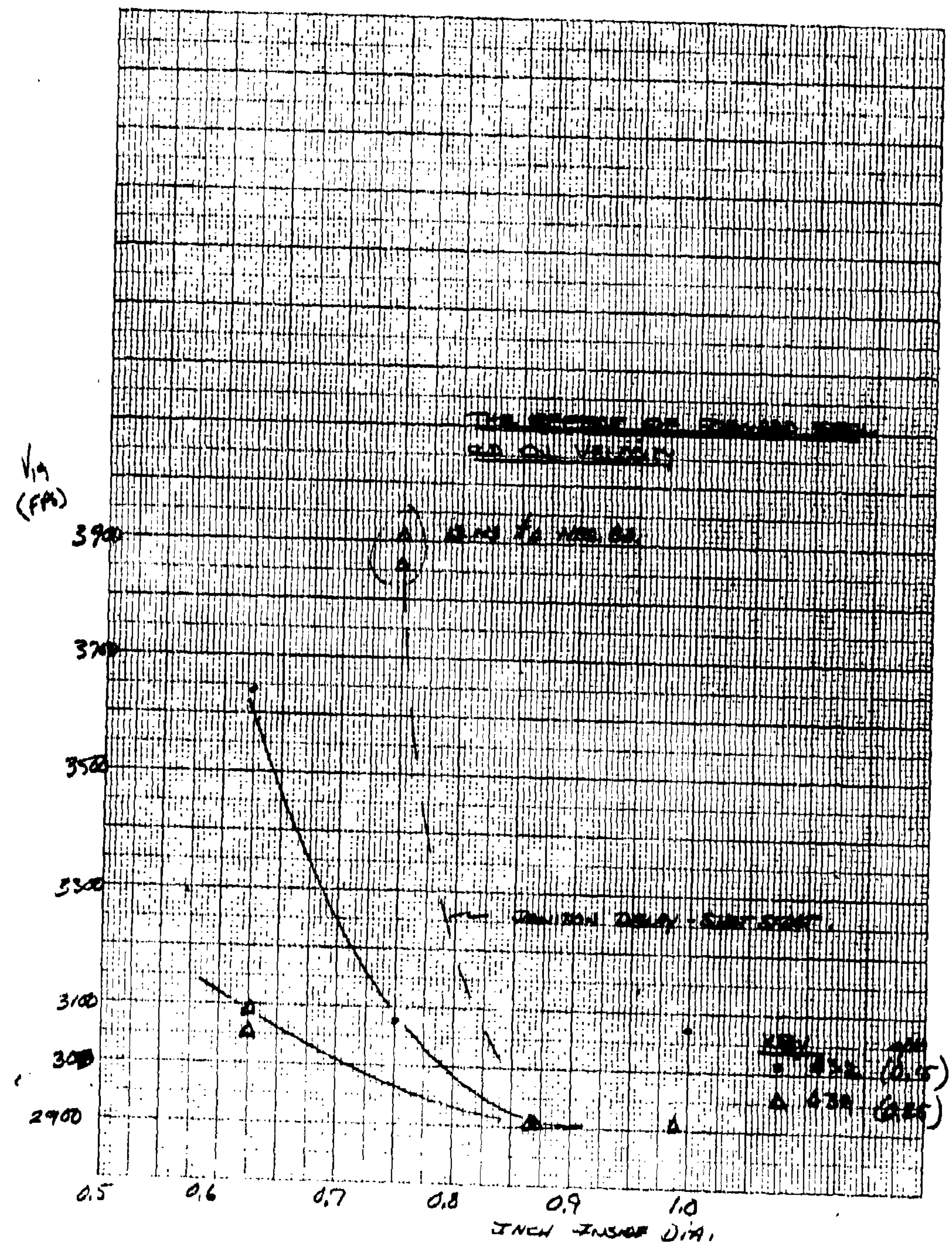
S/N 8



I.D. (IN)	Rd No.	P_{BR} (KPSI)	t_{PBA} (MS)	P_{BR} (KPSI)	t_{PZB} (MS)	V_{19} (FPS)	IGNITER
0.985	43	9	1.6	5	2.5	3068	0.15 (432)
	44	8	1.6	5	3.0	2900 EST	0.3 (439)
	45	0	—	0	50 –	NR	0.2 (439)
0.875	46	8	1.6	6	2.9	2905	0.15 (432)
	47	9	1.5	5	3.0	2905	0.25 (439)
	48	12	6.1	6	8.0	NR	0.25 (439)
0.750	49	9	1.6	5	2.7	3097	0.15 (432)
	50	0	12.8	0	12.8	3906	0.25 (439)
	51	0.75	10.0	0.5	10.4	3860	0.25 (439)
0.625	52	3	3	2	4	3646	0.15 (432)
	53	10	2	5	3.1	3097	0.25 (439)
	54	7	2.1	4	3.5	3068	0.25+ (439)

6 Aug 72

[illegible signature]



V_{19}
(FPS)
3900
3700
3500
3300
3100
3000
2900
0.5
0.6
0.7
0.8
0.9
1.0
INCH INSIDE DIA.

FWD GRAIN.

~~027 — 033 5479 4 wd grain~~
~~034 — 043 5440 " "~~

	wt (gms)	Length (in)	O.D. (in)		
02737	93.33	4.435	1.490	5479	S/N 7
02838	93.5	4.425	"		
039	93.6	4.435	"		
040	93.86	4.452	"		
041	93.94	4.450	"		
042	9327	4.445	"		
033	88.02	4.445	"		S/N 8
034	92.3	4.440	"	5440	
035	95.9	4.445	"		
036	84.5	4.455	"		
037	88.8	4.440	"		
038	92.24	4.445	"		
039	87.68	4.445	"		
040	84.36	4.445	"		
041	96.33	4.440	"		
042	8505	4.450	"		
043	91.27	4.445	"		
043	92.75	4445	"		

A/T
#446-9

S/N 7

	wt (gms)	LENGTH (IN)	OD (IN)	
037	44.7	1.308	1.490	
038	44.72	1.310	1.490	S/N 7
039	44.5	1.305	"	S/N 7
040	44.7	1.310	"	S/N 7
041	44.42	1.315	"	S/N 7
042	44.47	1.305	"	S/N 7
033	44.6	1.308	"	S/N 8
034	44.8	1.300	"	S/N 8
035	44.7	1.303	"	S/N 8
036	44.7	1.305	"	S/N 8
037	44.55	1.310	"	S/N 8
038	44.86	1.305	"	S/N 8
039	44.63	1.310	"	S/N 8
040	44.53	1.300	"	S/N 8
041	44.74	1.307	"	S/N 8
042	44.44	1.305	"	S/N 8
043	44.52	1.305	"	S/N 8
044	44.5	1.305	"	S/N 8

TEST REPORT

SERIAL NO. 9

OBJECTIVE: To evaluate Zytel (DuPont Nylon 6-12) as a seal material candidate.

REFERENCE: S/N 7

BACKGROUND: The seal configuration evaluated in S/N 7 (SK300520) was not satisfactory because of the square corner that protruded into the gas flow path at the barrel entrance. A seal configuration with an internal angle of 45 degrees was selected as a baseline to evaluate candidate seal materials (SK300522).

Two seal materials were selected for this seal concept evaluation. The materials were DuPont nylon 6-12, unfilled (Zytel 151) and 43 percent fiber filled (Zytel 77G43). The seals were machined from flat sample specimens 0.250 inch thick. The seals were bonded to the case with meta-cresol adhesive.

Ten rounds were assembled with:

Forward Charge	-	8472-1 propellant
Aft Charge	-	8446-9 propellant
Ignitor	-	TMS300432, 300439
Retention	-	40/10 NC/Mylar
Primer	-	32 S&W Pistol
Case	-	Nylon 6-12, 43 percent glass
Seal	-	Zytel 151 and 77G43

```
BALLISTIC DATA:  P1 MAX     P2 MAX     P3 MAX     VELOCITY     TIME
                 ----------------------------------------------------
                 ROUND NO--? 55
                    30.8      -1.3        7.93        3455      30.39
                    16.58      0          0
                 LS1 TO LS2 3476
                 P3 TO LS2 3465
                 ROUND NO--? 60
                    25.9      -.6         9.11        3097      23.86
                    49.39      0          0
                 LS1 TO LS2 3075
                 P3 TO LS2 3086
                 ROUND NO--? 56
                    21.4      -.1         5.91        2627      6.08
                    46.16      0          3.92
                 LS1 TO LS2 2644
                 P3 TO LS2 2635
                 ROUND NO--? 57
                    22        -.2         6.56        2782      6.15
                    47.48      0          2.27
                 LS1 TO LS2 2806
                 P3 TO LS2 2794
                 ROUND NO--? 58
                    31         0          9.28        3491      34.92
                    67.54      0          0
                 LS1 TO LS2 3476
                 P3 TO LS2 3464
                 ROUND NO--? 59
                    9.4        0          6.83        2015      16.79
                  .487
                    47.61      0          0
                 LS1 TO LS2 2012
                 P3 TO LS2 2014
                 ROUND NO--? 61
                    18         0          9.11        2830      9.72
                    54.49      0          .58
                 LS1 TO LS2 2806
                 P3 TO LS2 2818
                 ROUND NO--? 62
                    22.3       0          6.93        2806      7.04
                    49.32      0          3.56
                 LS1 TO LS2 2806
                 P3 TO LS2 2806
                 ROUND NO--? 63
                    23.8       .2         9.53        3012      21.67
                    70.32      0          .3
                 LS1 TO LS2 2989
                 P3 TO LS2 3000
                 ROUND NO--? 64
                    25.1       .1         6.65        2957      6.9
                    49.27      .04        3.05
                 LS1 TO LS2 2934
                 P3 TO LS2 2946
```

DISCUSSION: The seals remained attached to the cartridge cases and appeared to withstand the ballistic environment without severe erosion. The seal configuration was acceptable as a baseline design. One seal made from the glass filled nylon cracked longitudinally in two places. The break was a hoop tensile failure and was probably the combined result of an undersized diameter and the low percent elongation of the material. All the unfilled seals functioned without failure. The erosion of the sealing surface indicated a gas leak was present but no damage to the gun was observed.

The ballistic performance data illustrates the effect of a low RQ forward charge. Action times up to 35 milliseconds were recorded and blowby pressures were only up to 6 Kpsi. Rounds with similar components and baseline (100 RQ) forward charges produce 5 millisecond action times and blowby pressures up to 10 Kpsi. The forward charge provides an important contribution to the interior ballistics of the cartridge.

The cartridge cases that utilized ignitor TMS300432 all cracked at the base. The cracks originated at the ignitor cavity and propagated across the base and forward along the case sidewall for approximately three inches. The cases were extracted from the gun chamber intact.

CONCLUSION: The unfilled nylon 6-12 material was selected for continued development. The seal configuration described with an internal bevel was determined to be satisfactory as a baseline for subsequent seal material evaluations.

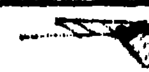
The low RQ forward charge was not desirable in this cartridge configuration. A different ignitor such as black powder with a less brizant energy output would be desirable.

25MM PLASTIC CASE
AMMUNITION DEVELOPMENT

S/N: 9
DATE: 12 JULY 79
ENGR: CARY
AMMO: EATON

OBJECTIVE: TO EVALUATE BYTEL (DUPONT NYLON) AS A CANDIDATE SEAL MATERIAL

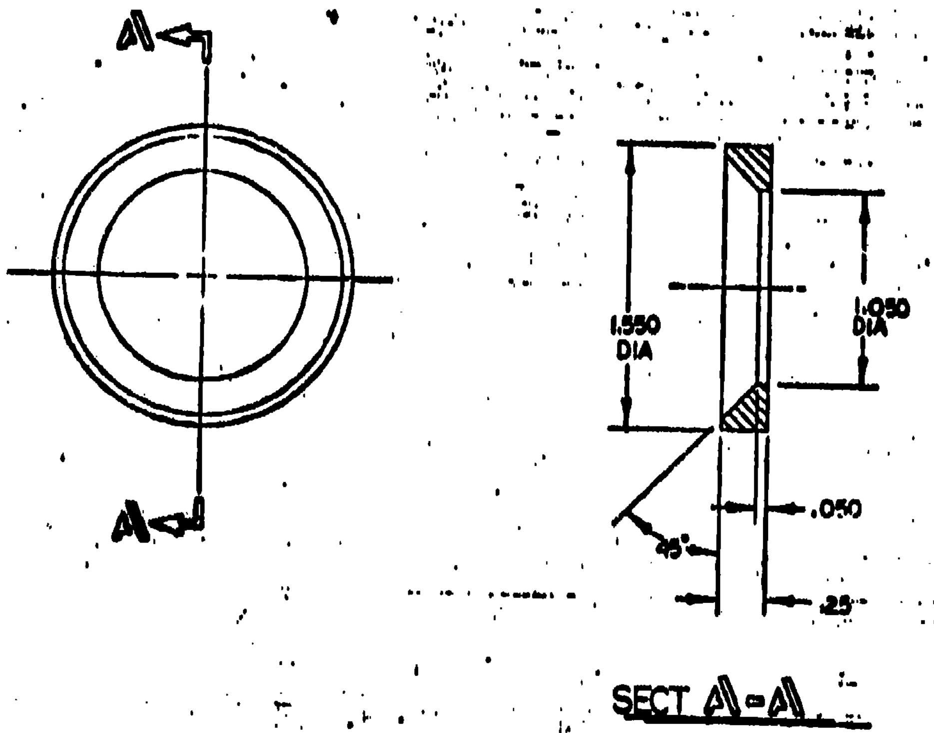
Test Fixture: IITRI, UNIVERSAL, RIA.
Cartridge Case: Dwg. No. SK 300460, Rev.____, Mat'l NYLON 6/12 43% GLASS
Dwg. No. ________, Rev.____, Mat'l________.
Projectile: Dwg. No. 300347, Rev. A, Plastic Band, 3000 Grain.
Primer: Type DARCL, Lot No.________, No.________.
Flash Tube: C325SW, 38 Special, ________.
Projectile Retention: 40 Mil NC, 10 Mil Mylar, LOCTITE IS150 TO GRAINS
Ignitor: TMS 300432, 300439, Seals: BYTEL 151, 77G43 SK 300532
Propellant: Fwd Charge 8472-1, Lot No. 81-435.
Aft Charge 8446-9, Lot No. 89-482.
Insert —, Lot No.________.



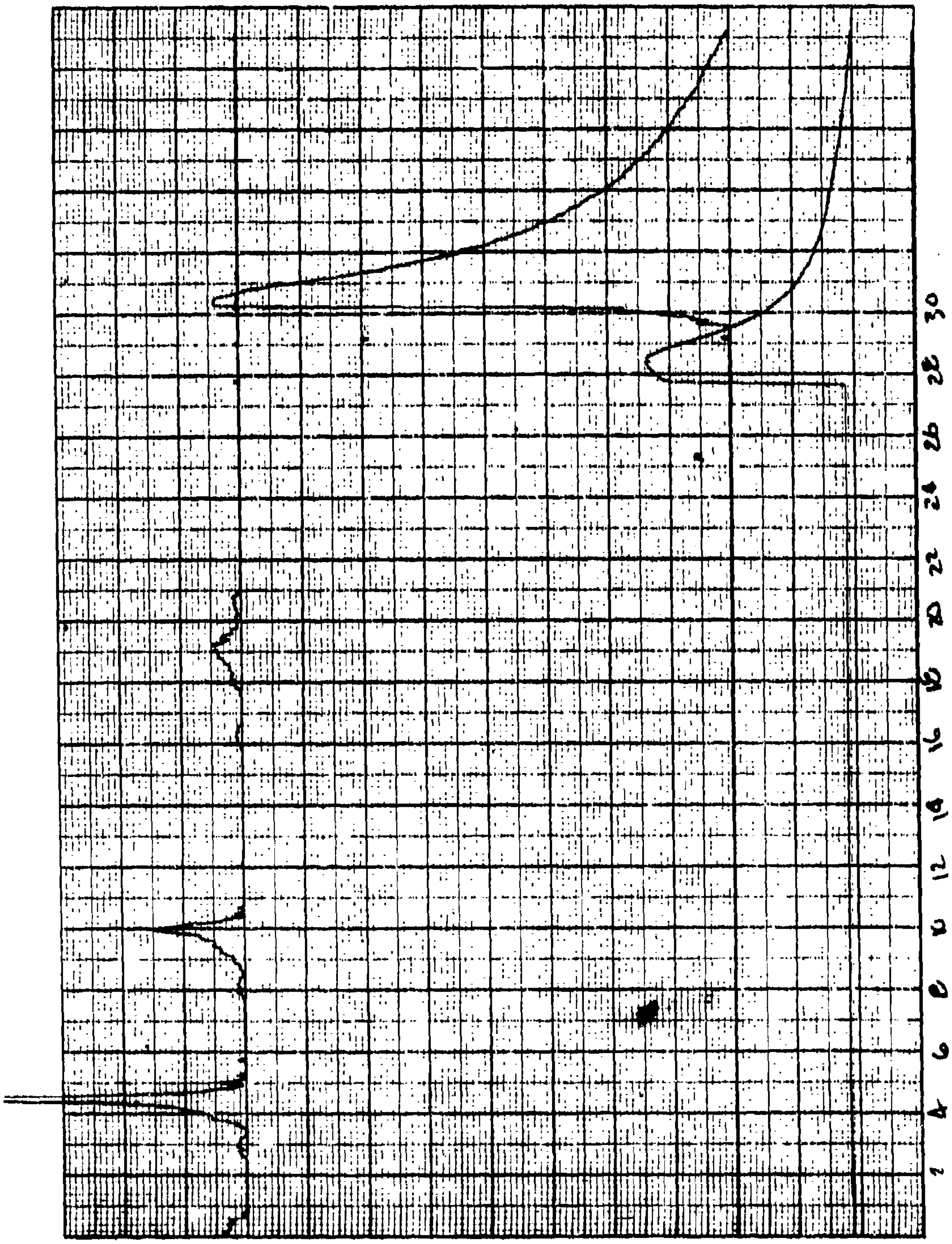
REMARKS: ROUND LENGTH 6.075/6.085" (0.020/0.030 CRUSH W)

ROUND NO.	PROPELLANT WT (GRAMS) FWD	AFT	INSERT	TOTAL PROP. WT (GRAMS)	IGNITOR WT (GRAMS)
BYTEL 151					TMS 432
55	91.4	44.8	—	136.2	0.2
56	93.6	44.4	—	138.0	0.3
57	91.2	44.6	—	135.6	0.25
58	93.9	44.7	—	138.6	0.20
59	93.3	44.8	—	138.1	0.225
BYTEL 77G43					
60	94.5	44.4	—	138.9	0.2
61	92.7	44.8	—	137.5	0.3 (439)
62	90.1	44.7	—	134.8	0.25 (439)
63	93.0	44.7	—	137.7	0.2 (439) 0.1 (432)
64	92.9	44.8	—	137.7	0.2 (439)

FORM NO. SG-555-81



SEAL
25MM PLASTIC CASE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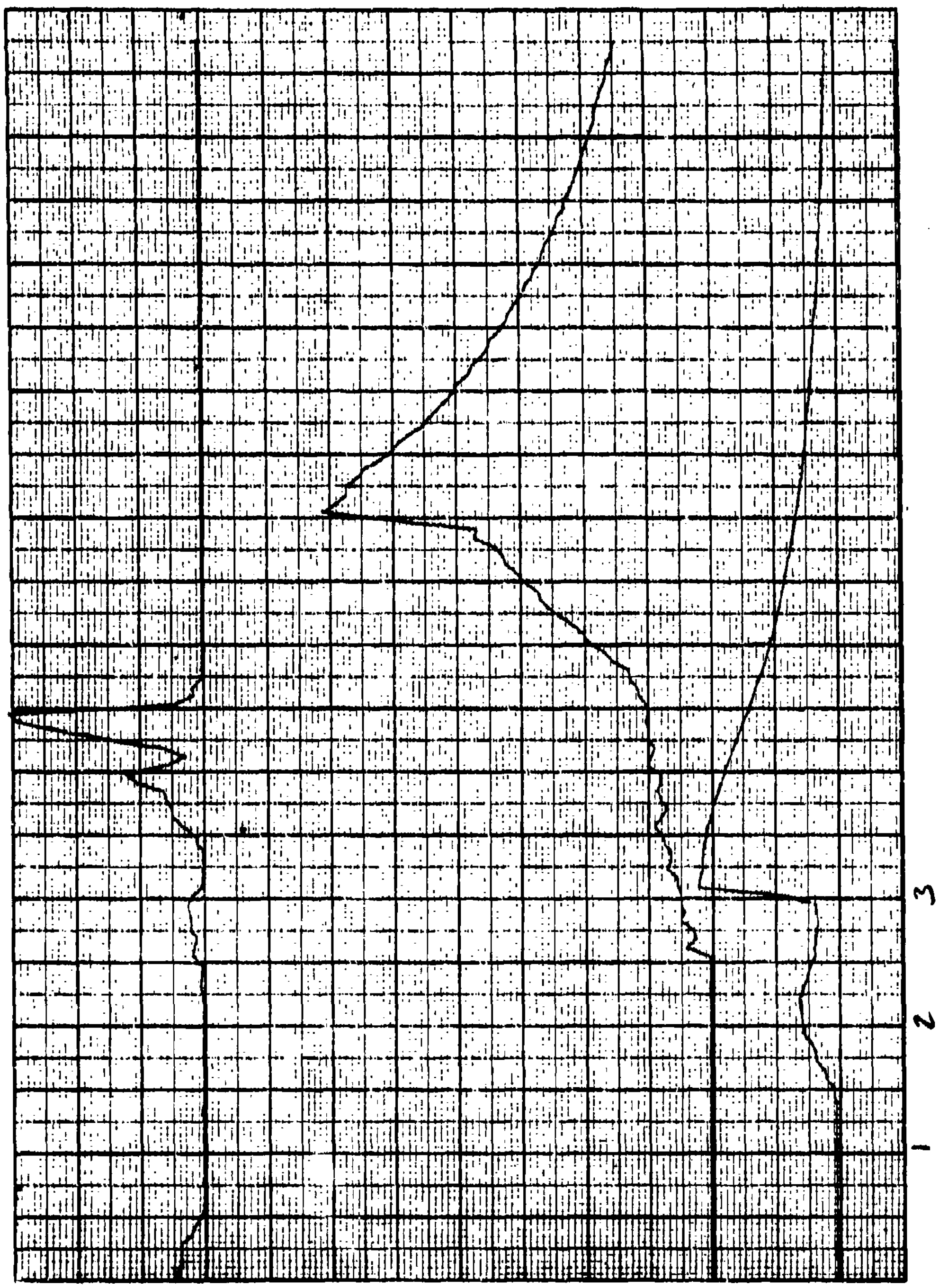
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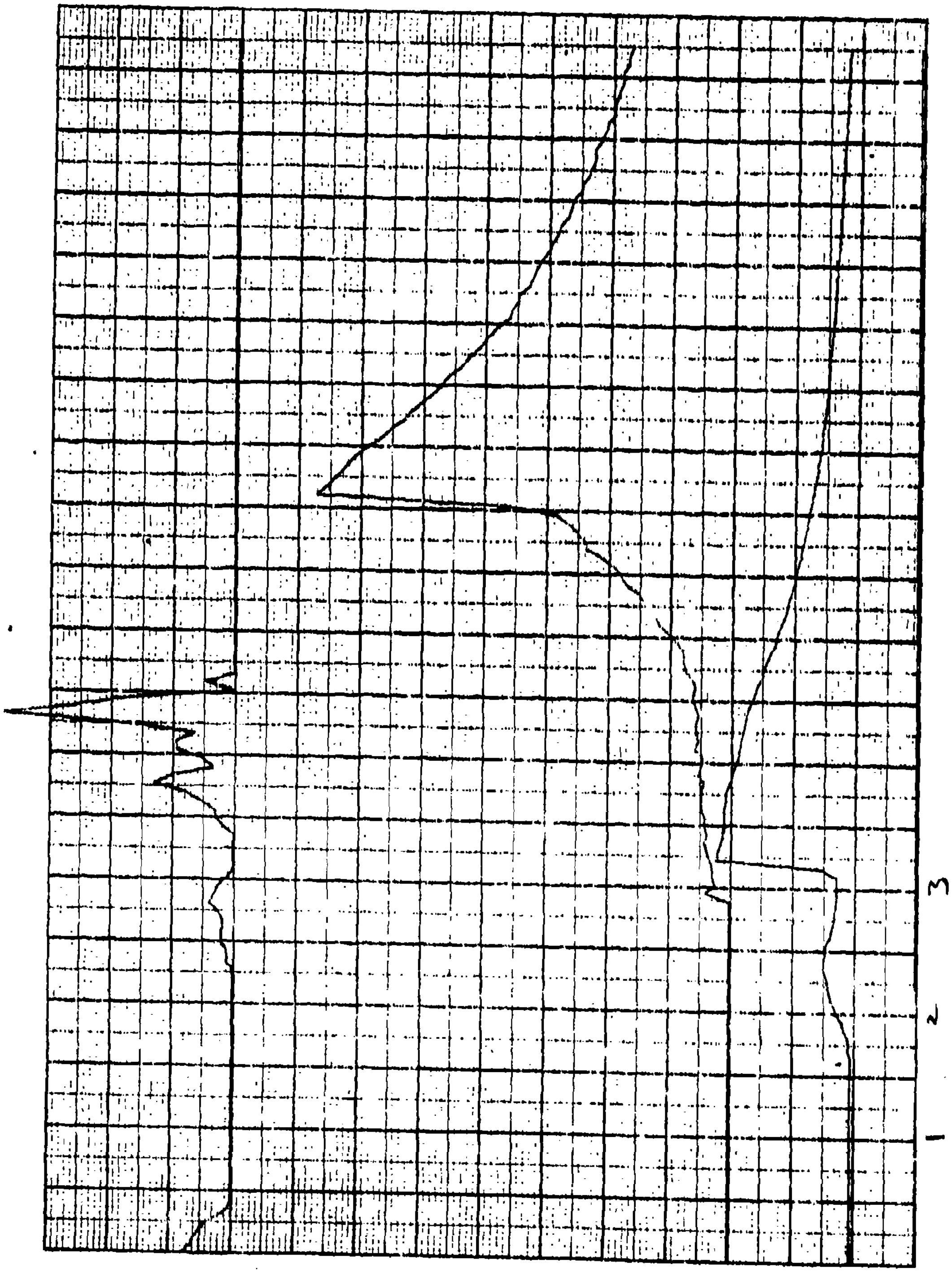
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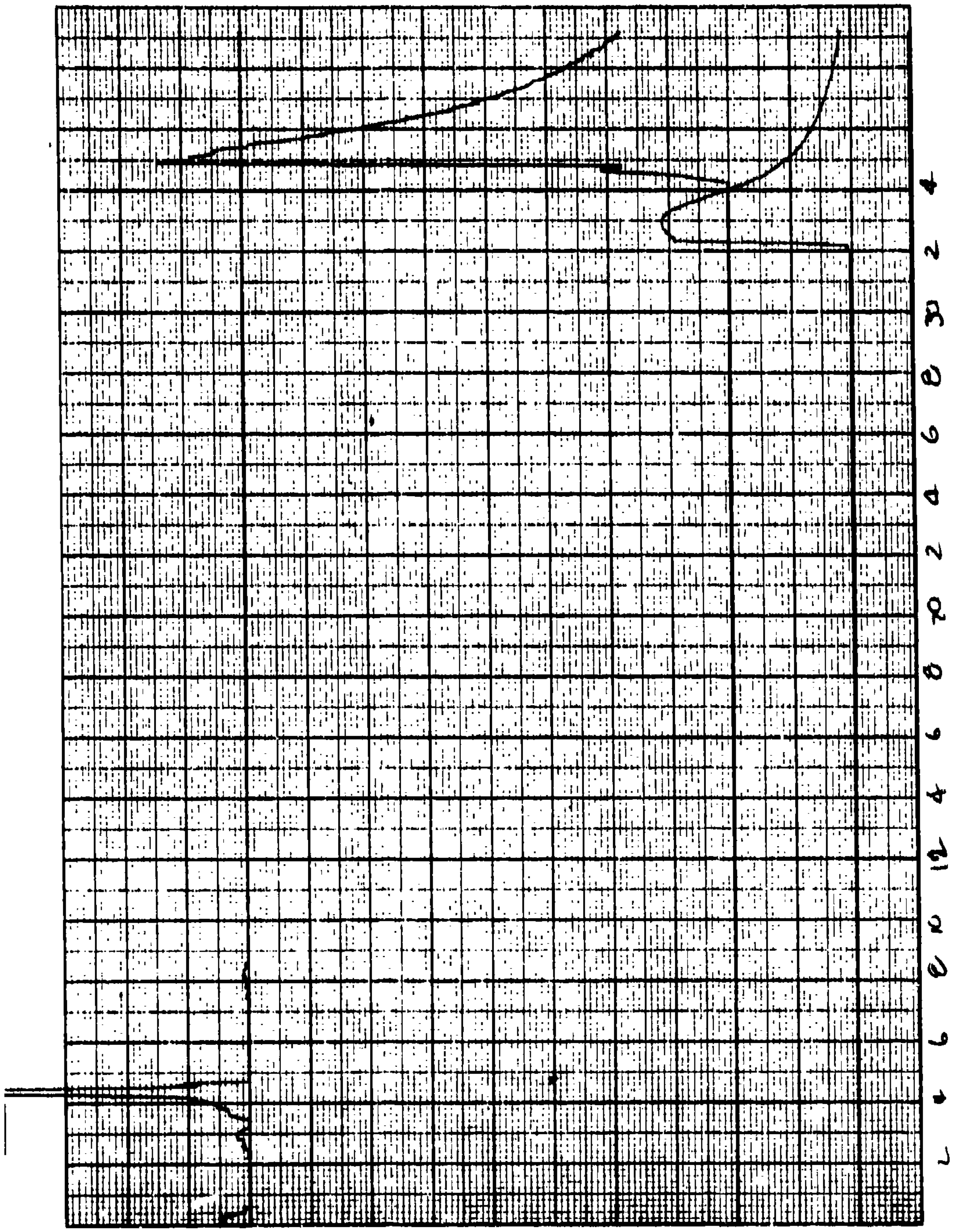

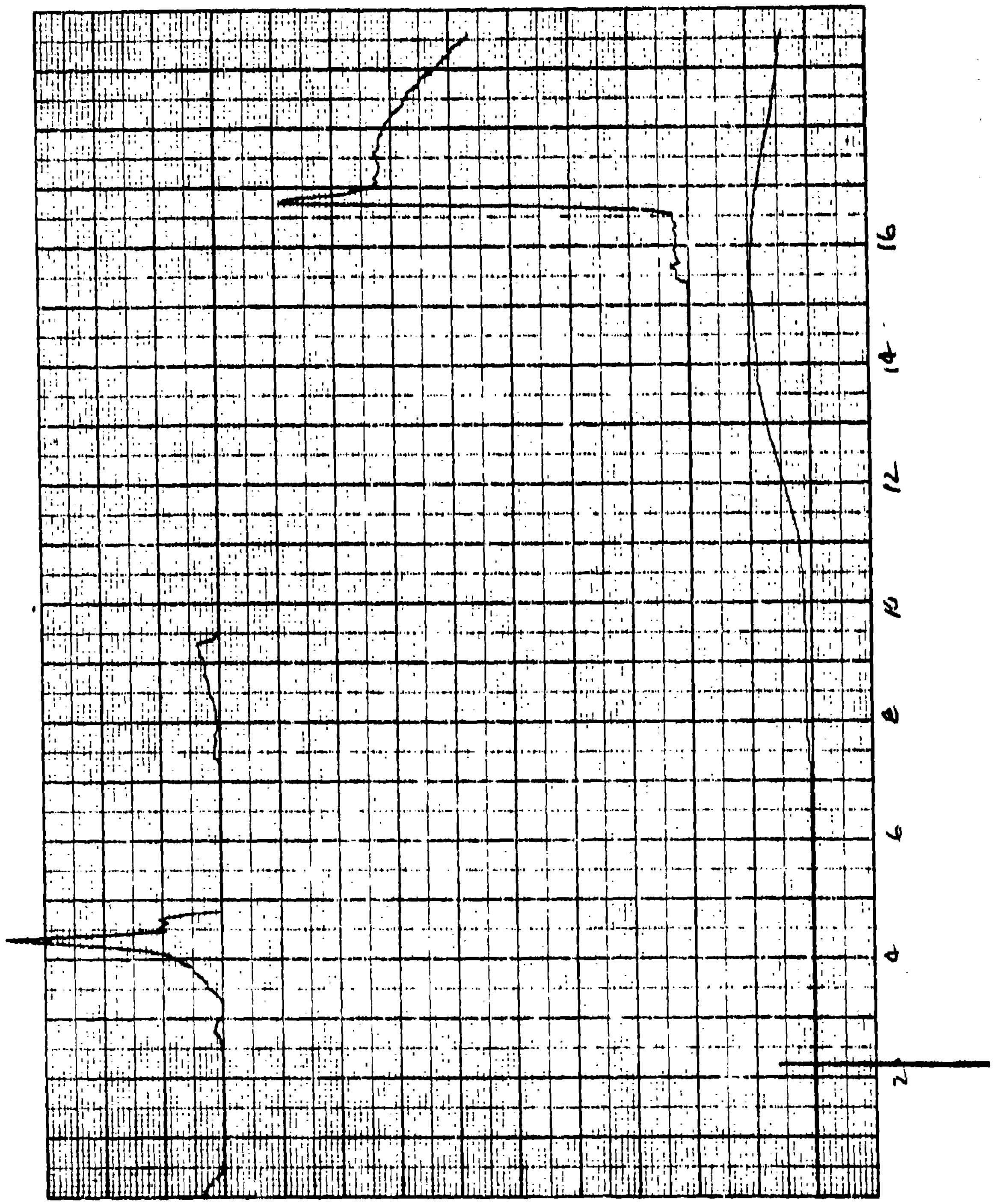
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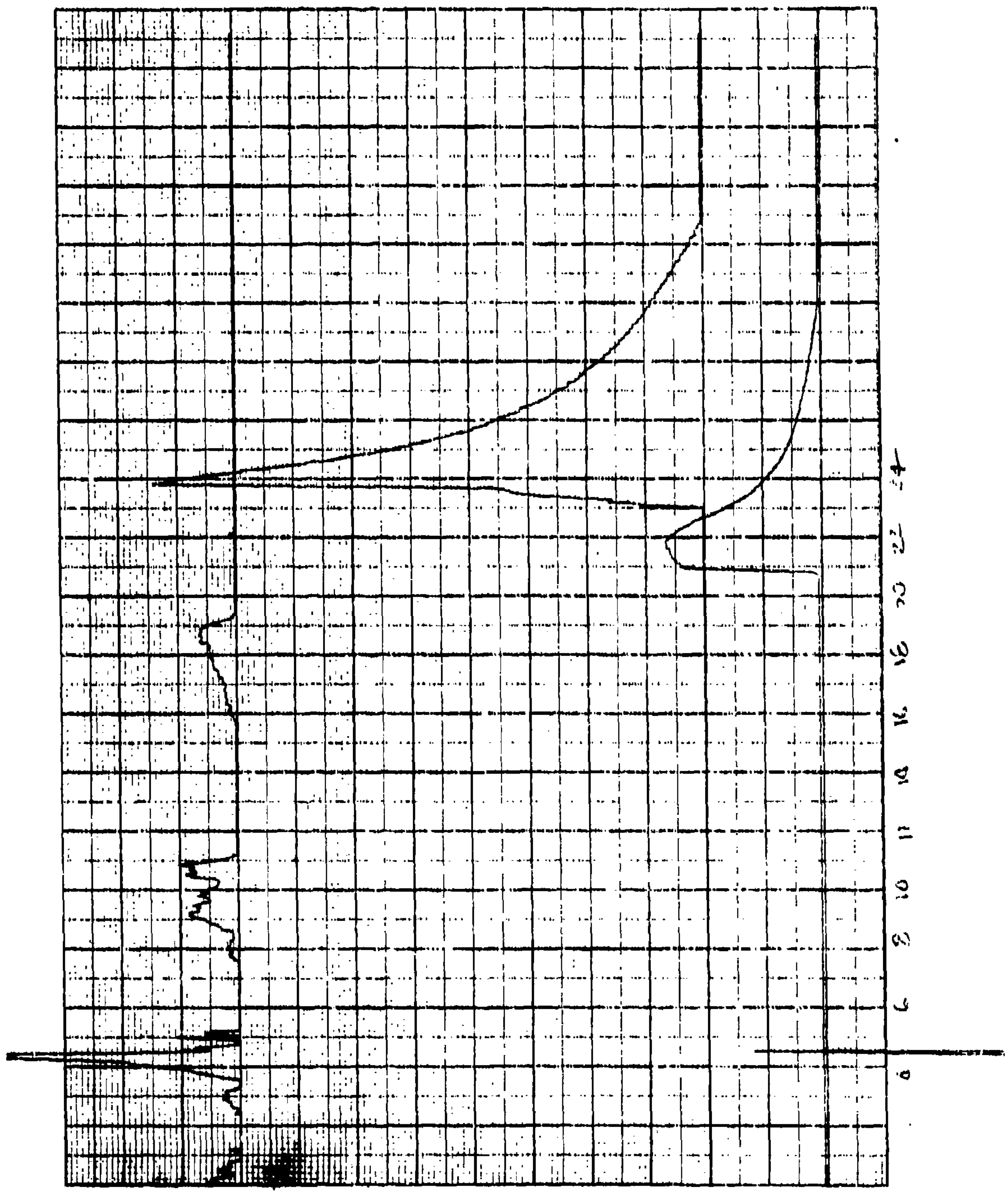

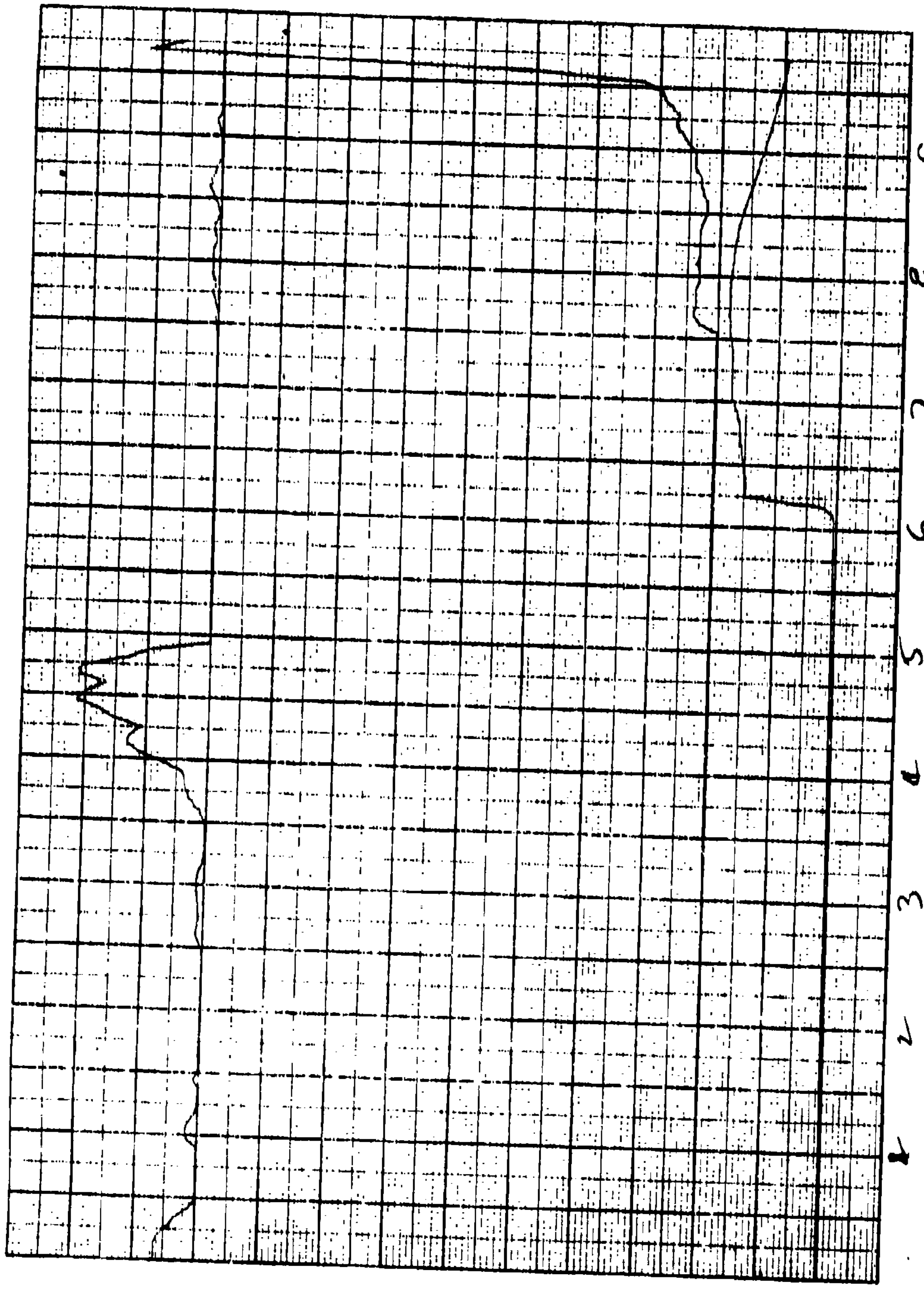
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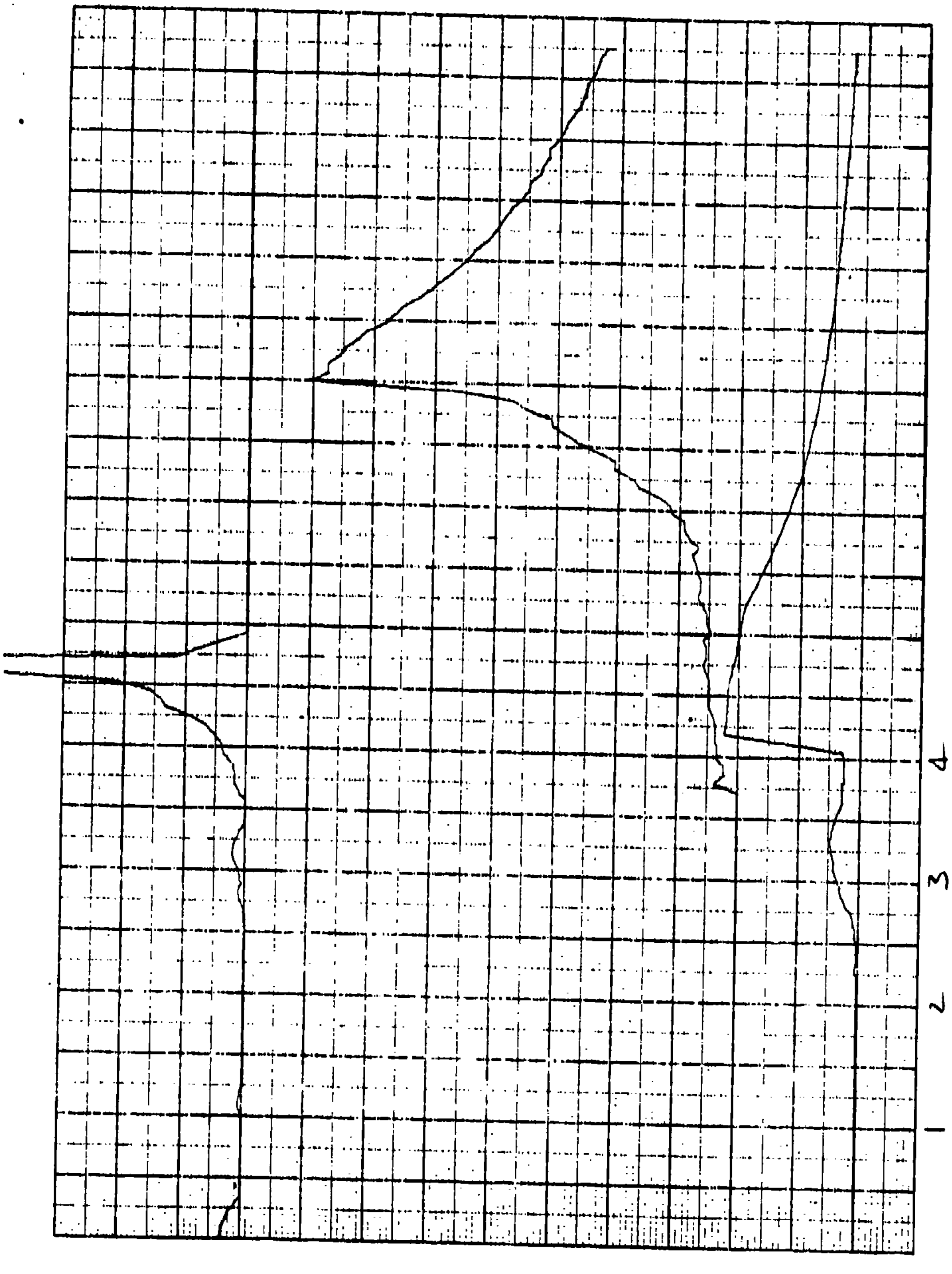
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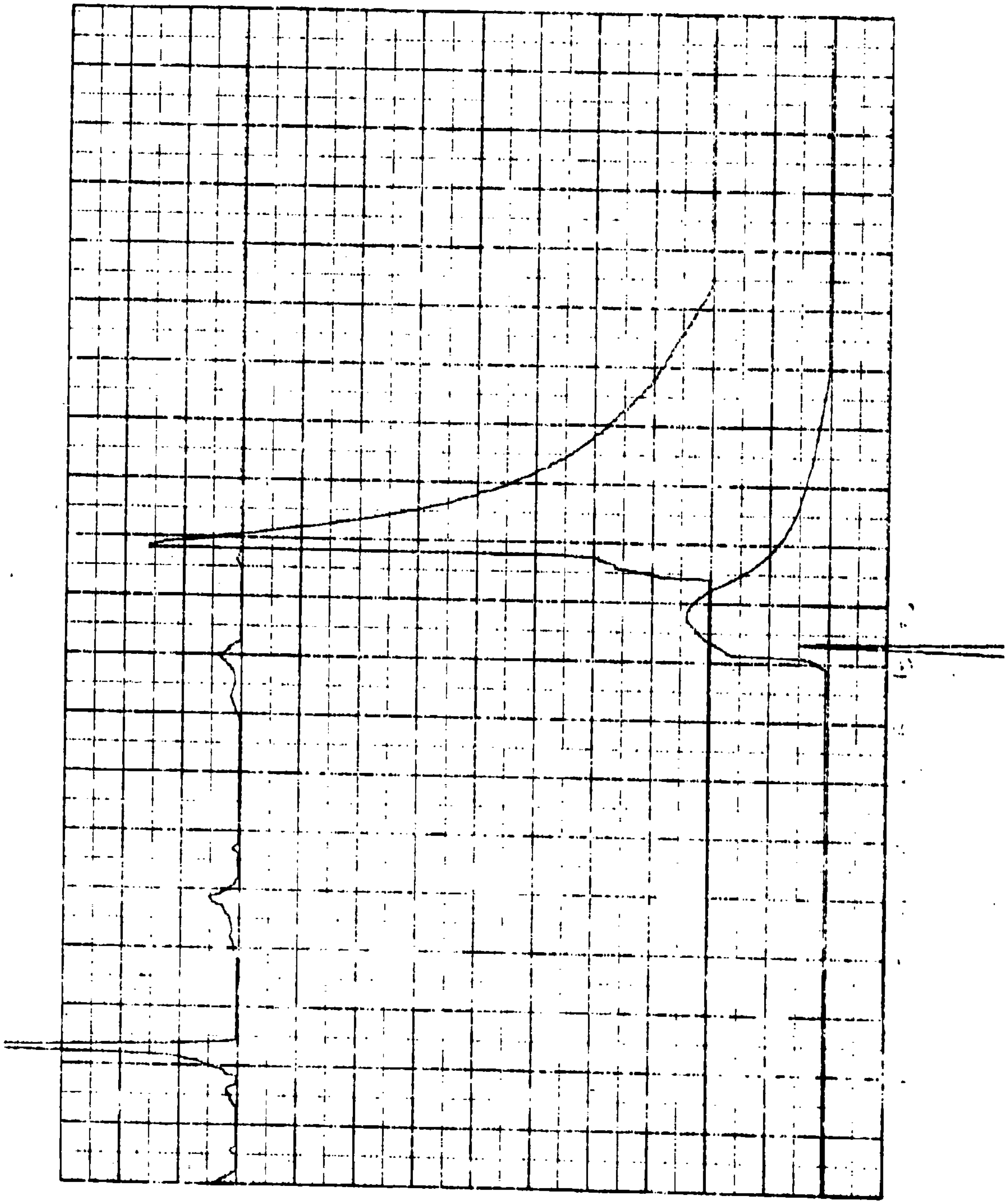

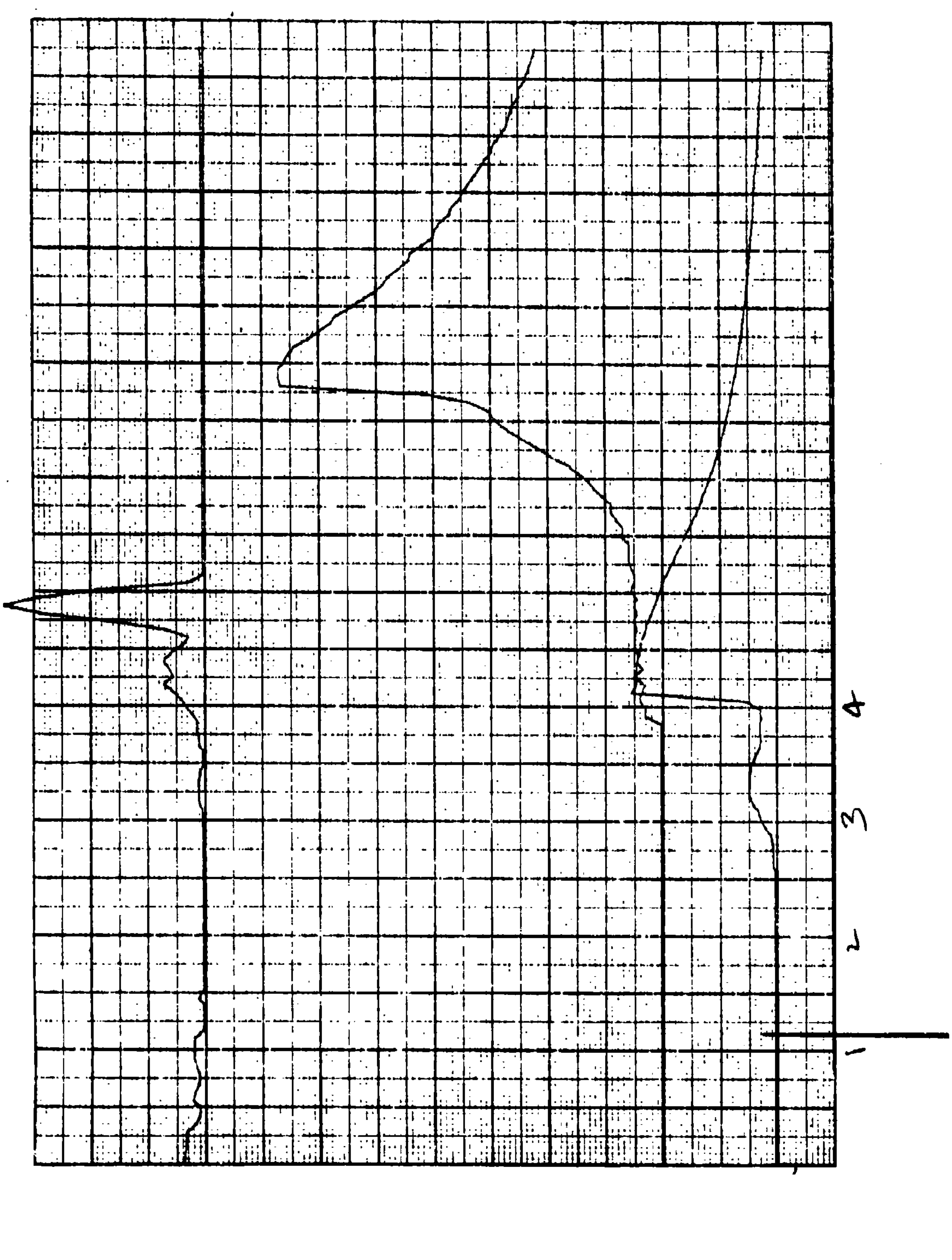
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TEST REPORT

SERIAL NO. 10

OBJECTIVE: To evaluate Torlon (AMOCO polyamide-imide) as a candidate seal material.

REFERENCE: S/N 9

BACKGROUND: Torlon is a new thermoplastic with exceptional physical properties. Tensile strengths are up to 27,000 psi and elongation is up to 13 percent. These properties are considered desirable for a seal material.

Seals were machined from flat sample blanks 0.170 inch thick of two material formulations 4203 and 4301. Torlon 4301 contains graphite and teflon additives for lubrication properties. It has tensile strengths of 20,000 psi and elongations of 6 percent. The seal configuration was described in SK300522. The seals were bonded in the cartridge case with pliobond 20 adhesive.

Four rounds were assembled with:

Forward Charge	-	8446-9 propellant
Aft Charge	-	8446-9 propellant
Ignitor	-	TMS 300439
Retention	-	40/10 - NC/Mylar
Primer	-	32 S&W Pistol
Case	-	Nylon 12, 38 percent glass
Seal	-	Torlon 4203 and 4301

BALLISTIC DATA:

```
                                          @ 11 Feet
P1 MAX       P2 MAX       P3 MAX       VELOCITY      TIME
-----------------------------------------------------------
ROUND NO--? 65
   36.7        -1.2          5.47          3315       5.12
   32.39        0            0
LS1 TO LS2 3297
P3 TO LS2 3306
ROUND NO--? 66
   39          -.3           6.69          3419       5.87
   48.49        0            1.18
LS1 TO LS2 3402
P3 TO LS2 3412
ROUND NO--? 67
   31.4        -.1           4.98          2585       5.94
   45.17        0            6.24
LS1 TO LS2 2580
P3 TO LS2 2582
ROUND NO--? 68
   49.6         0            8.69          4181       39.11
   68.59        0            0
LS1 TO LS2 4046
P3 TO LS2 4074
```

DISCUSSION: The torlon seals were partially acceptable. Two were ejected from the gun and one seal was cracked longitudinally. Examination of the seals indicated that the outside diameter was 0.060 inch below tolerance and no per drawing SK300522. The reduced diameter required the seal to expand beyond the yield point and the high strain rate generated by the combustion gases caused the material to fail. The tests should be repeated with seals of the correct diameter.

The cartridge cases did not crack and this was attributed to the slow burning ignitor THS 300439.

The ballistic performance indicates that blowby occurred in three rounds and a stop action in one round. The erratic behavior was not determined but was believed to be related to an ignitor malfunction. Blowby pressure ranged from 5 Kpsi to 10 Kpsi indicating premature ignition of the aft charge.

CONCLUSION: The torlon seal results were inconclusive and the tests should be repeated with seals of the proper diameter dimensions.

25MM PLASTIC CASE
AMMUNITION DEVELOPMENT

S/N: 10
DATE: [illegible]
ENGR: [illegible]
AMMO: [illegible]

OBJECTIVE: TO EVALUATE TORLON (AMOCO - POLYAMIDE-IMIDE) AS A CANDIDATE SEAL MATERIAL

Test Fixture: IITRI, UNIVERSAL, RIA.
Cartridge Case: Dwg. No. SK 300460, Rev.____, Mat'l NYLON 12, 38% GLASS
Dwg. No. ________, Rev.____, Mat'l ________.
Projectile: Dwg. No. 300347, Rev. A, Plastic Band, 3000 Grain.
Primer: Type [illegible], Lot No.________, No.________.
Flash Tube: 125SAW 38 Special, ________. LOCTITE 15150 TORLON
Projectile Retention: 40 Mil NC, 10 Mil Mylar,
Ignitor: TMS 300499, Seals: TORLON [illegible] SK 300[illegible]
Propellant: Fwd Charge [illegible], Lot No. [illegible].
Aft Charge [illegible], Lot No. [illegible].
Insert ________, Lot No.________.

REMARKS: ROUND LENGTH 6.075"/ 6.085" (0.010 [illegible]" CALEN CP)

ROUND NO.	PROPELLANT WT (GRAMS) FWD	AFT	INSERT	TOTAL PROP. WT (GRAMS)	IGNITOR WT (GRAMS)
					TMS 300499
65	94.6	44.6	—		0.25
66	94.6	45.0	—		0.25
67	94.8	44.9	—		0.25
68	94.8	44.3	—		0.25

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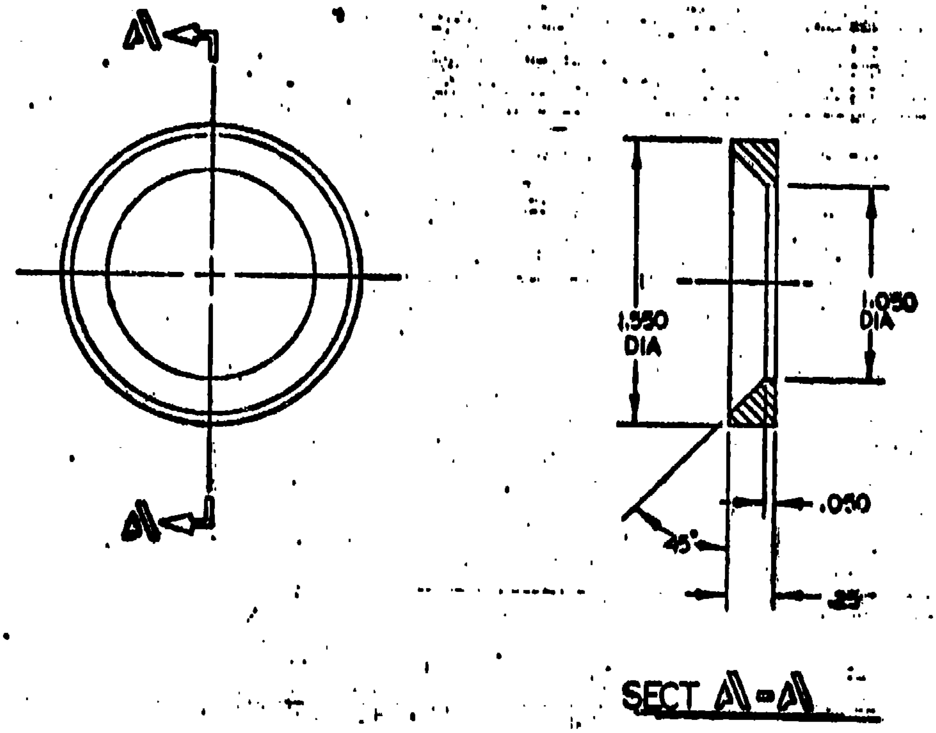
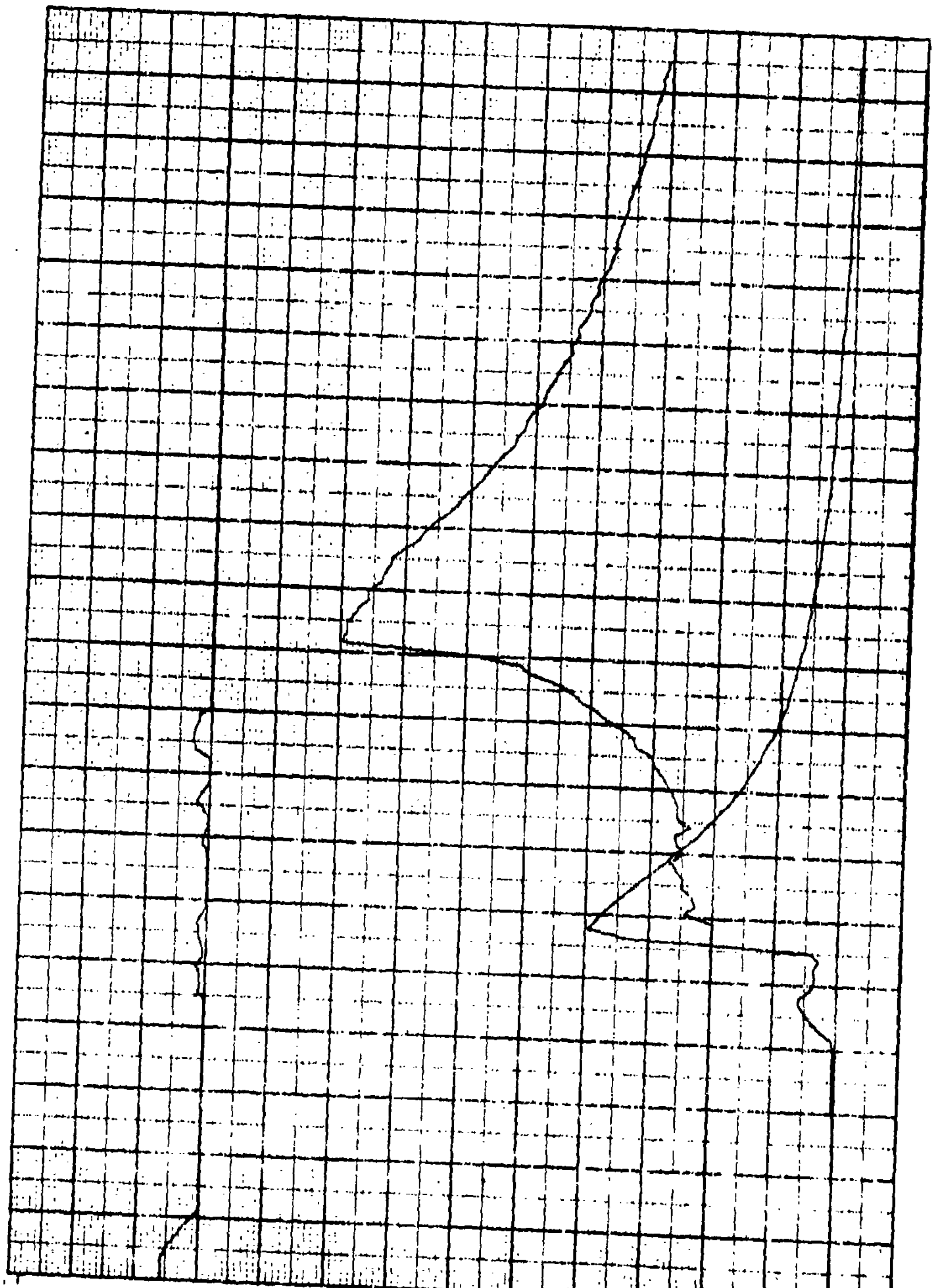
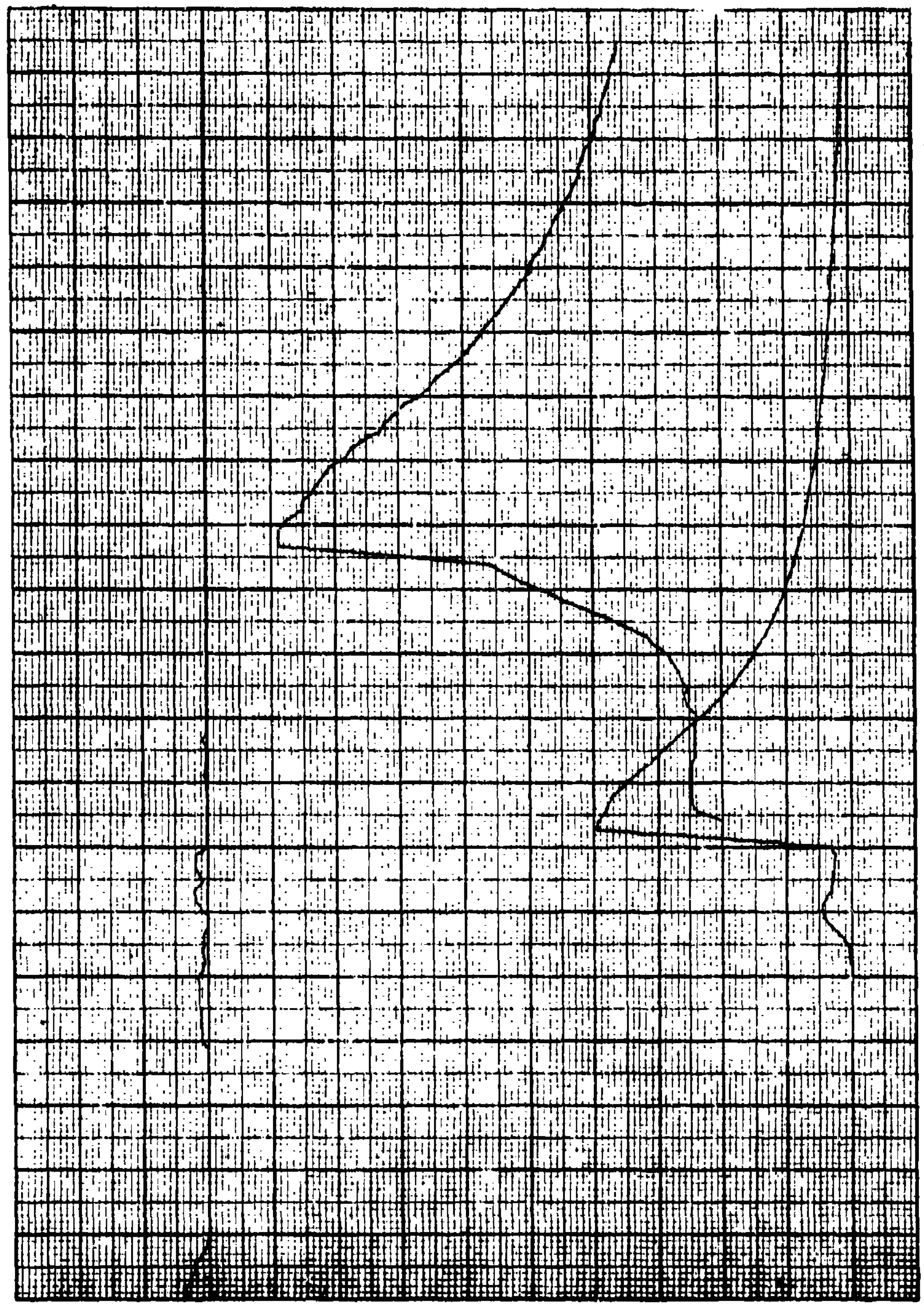
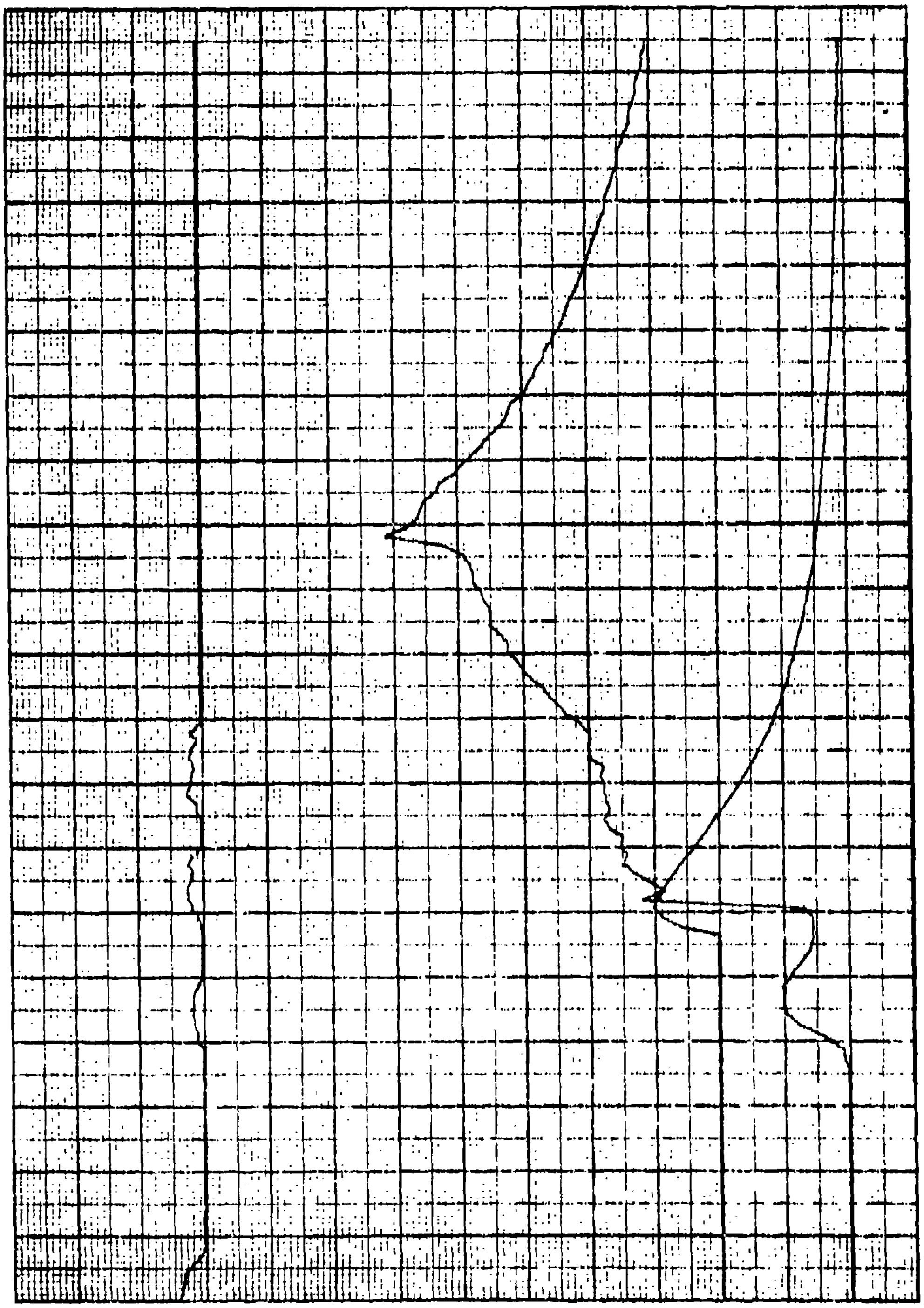
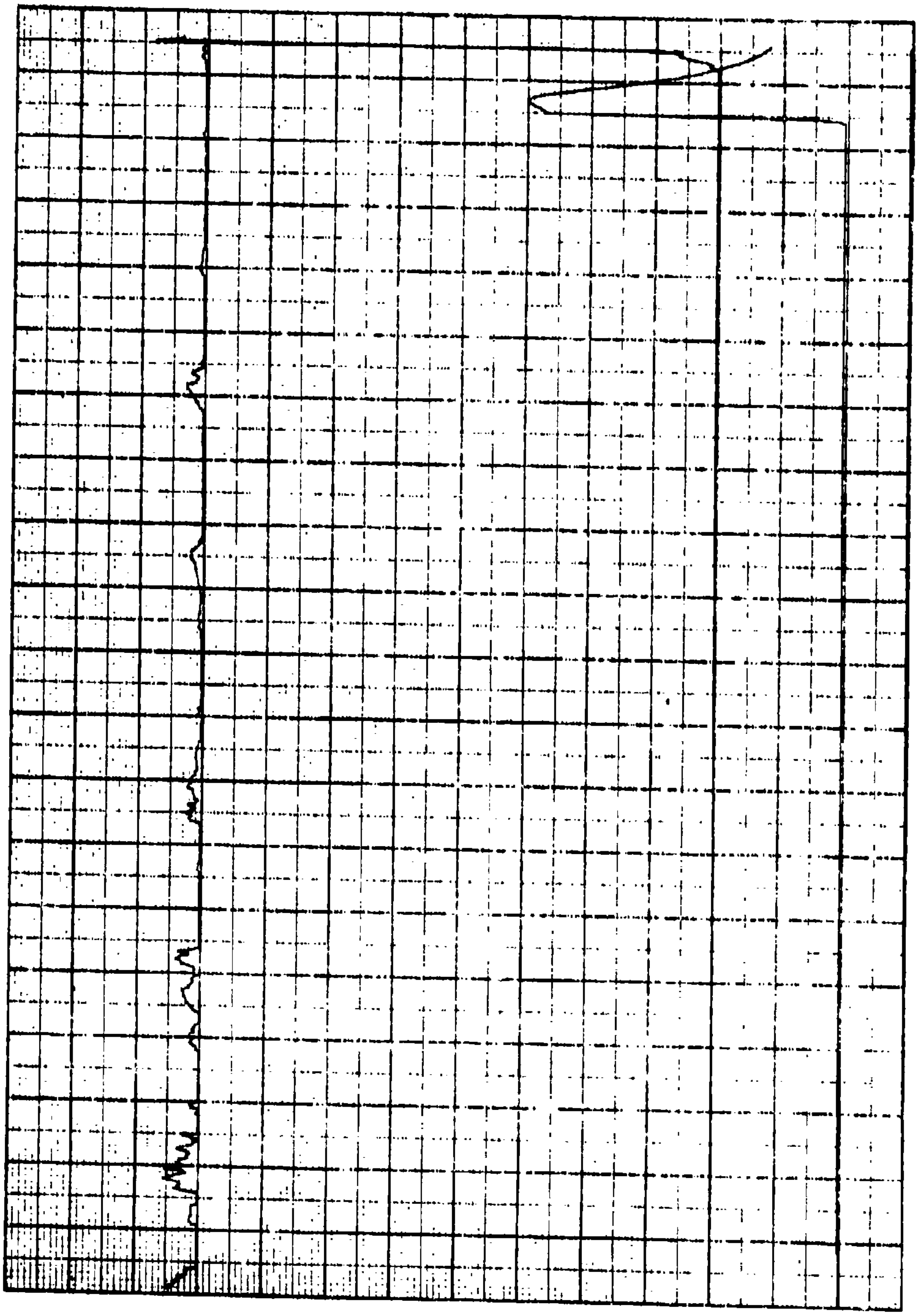


SEAL
25MM PLASTIC CASE









TEST REPORT

SERIAL NO. 11

OBJECTIVE: To observe the effect of an interference forward seal on ballistic performance.

REFERENCE: S/N 8

BACKGROUND: Test series S/N 8 indicated that velocity improvements were achieved by providing an interference fit between the projectile and the forward seal. The tests showed that the projectile decelerated prior to engraving and the reduced annular flow path around the projectile reduced the blowby. The seals, however, were ejected from the gun and analysis of the interference mechanism was not performed.

A seal with an increased cross section was selected. The seals were made in two length to width radios, 1:1 and 1:2. The inside diameter was 0.928 inch to provide an interference fit with the projectile ogive. The bourrelet diameter was 0.986 inch.

Six rounds were assembled with:

Forward Charge	-	5479 propellant
Aft Charge	-	8446-9 propellant
Ignitor	-	TMS 300432
Retention	-	40/10 NC/ Mylar
Primer	-	32 S&W Pistol
Case	-	Nylon 12, 33 percent glass
Seal	-	ABS, unfilled

BALLISTIC DATA:

```
P1 MAX     P2 MAX     P3 MAX     VELOCITY     TIME
--------------------------------------------------
ROUND NO--769
   32.7      -1.3       5.09       3156       5.12
   31.73      0          .35
LS1 TO LS2 3166
P3 TO LS2 3161
ROUND NO--770
   34         -.6       5.63       3097       5.12
   41.72      0         1.93
LS1 TO LS2 3075
P3 TO LS2 3086
ROUND NO--771
   31.6       -.2       5.02       3039       5.32
   43.16      0         4.02
LS1 TO LS2 2066
P3 TO LS2 2655
```

ROUND NO.72 — HANGFIRE —

```
ROUND NO--773
   99.9       -.1       6.01       3830       56.62
   81.28      0         0
LS1 TO LS2 73
P3 TO LS2 3175
ROUND NO--774
   99.9       -.1       6.31       3833       43.09
   79.05      0         0
LS1 TO LS2 3910
P3 TO LS2 3846
```

DISCUSSION: The ballistic performance was similar and reproducible in each group but distinctly different between each group. The group with the 0.25 inch long seal had uniform blowby but at a reduced magnatude than normally observed. The blowby averaged 7 Kpsi.

The group with the 0.5 inch long seal produced long action time stop ballistics. This indicates that the projectile stopped and the ignitor was not energetic enough to ignite the propellant in the available free volume.

The significant differences in ballistic performance between the two cartridge configurations indicate that the forward seal can be made to have a pronounced effect on cartridge performance.

Each of the seals were ejected from the test fixture. The cases did not crack at the base as normally observed with glass contents greater than 33 percent. The absence of cracks was observed in previous tests with TMS 300432 and 33 percent glass filled nylon 12 cases.

CONCLUSION: The forward seal was shown to have a significant influence on ballistic performance and is a method of controlling the interior ballistic cycle.

Additional tests are recommended with the internal beveled seal configuration and a slower burning ignitor like Class 3 black powder.

25MM PLASTIC CASE
AMMUNITION DEVELOPMENT

S/N: 11
DATE: 29 DEC 74
ENGR: CARY
AMMO: CATR...

OBJECTIVE: To Observe The Effect Of An Interference Forward Seal On Ballistic Performance

Test Fixture: IITRI, ~~UNIVERSAL~~, RIA.
Cartridge Case: Dwg. No. SK 300460, Rev.____, Mat'l Nylon 12, 33% Glass
Dwg. No. ________, Rev.____, Mat'l________.
Projectile: Dwg. No. 300347, Rev. A, Plastic Band, 3000 Grain.
Primer: Type PISTEX, Lot No.________, No.________.
Flash Tube: 32560, 38 Special, ________.
Projectile Retention: 40 Mil NC, 10 Mil Mylar, Loctite 15160 Bond To ___ Grams
Ignitor: TMS 300432, Seals: Unfilled ABS
Propellant: Fwd Charge 5479, Lot No. 6-82
Aft Charge 8446-9, Lot No. 6-83
Insert ________, Lot No.________.

TMS WAD 1x1 TISSUE

0.25" 0.50" 0.25" 0.50" 0.928" I.D

REMARKS: Seals Bonded To Case With Pliobond 20.

SEAL LENGTH

ROUND NO.	PROPELLANT WT (GRAMS) FWD	AFT	INSERT	TOTAL PROP. WT (GRAMS)	IGNITOR WT (GRAMS)
0.25"					TMS 432
69	95.5	45.1	-	140.6	0.15
70	95.7	45.1	-	140.8	0.15
71	96.4	45.0	-	141.4	0.15
0.50"	WT BEFORE MACHINING				
72	95.6	45.2	-	140.8	0.15
73	95.3	44.0	-	139.3	0.15
74	95.6	45.4	-	141.0	0.15
	Actual Lower Less				

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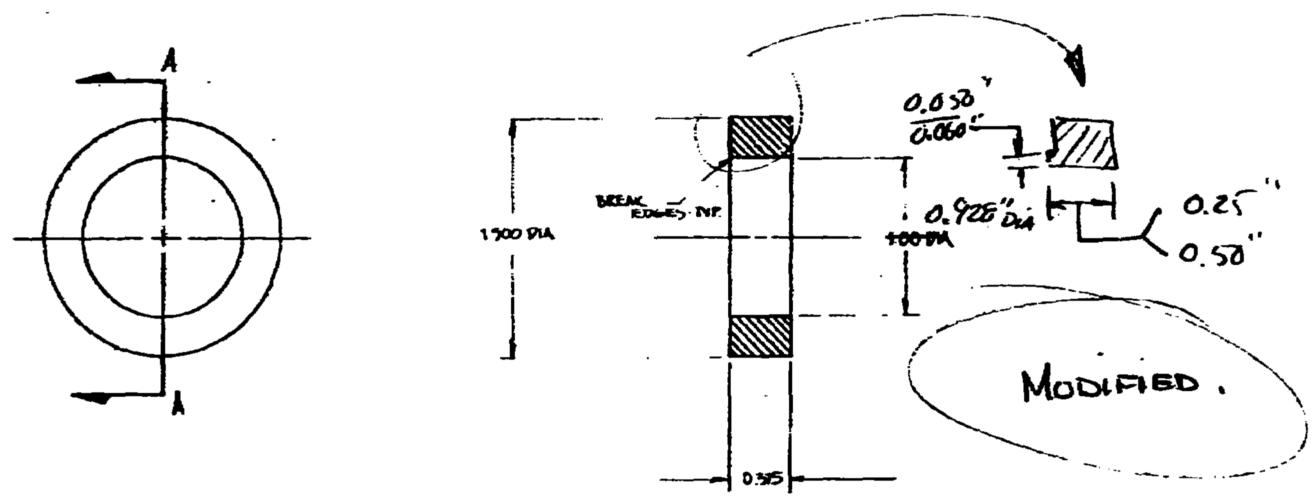
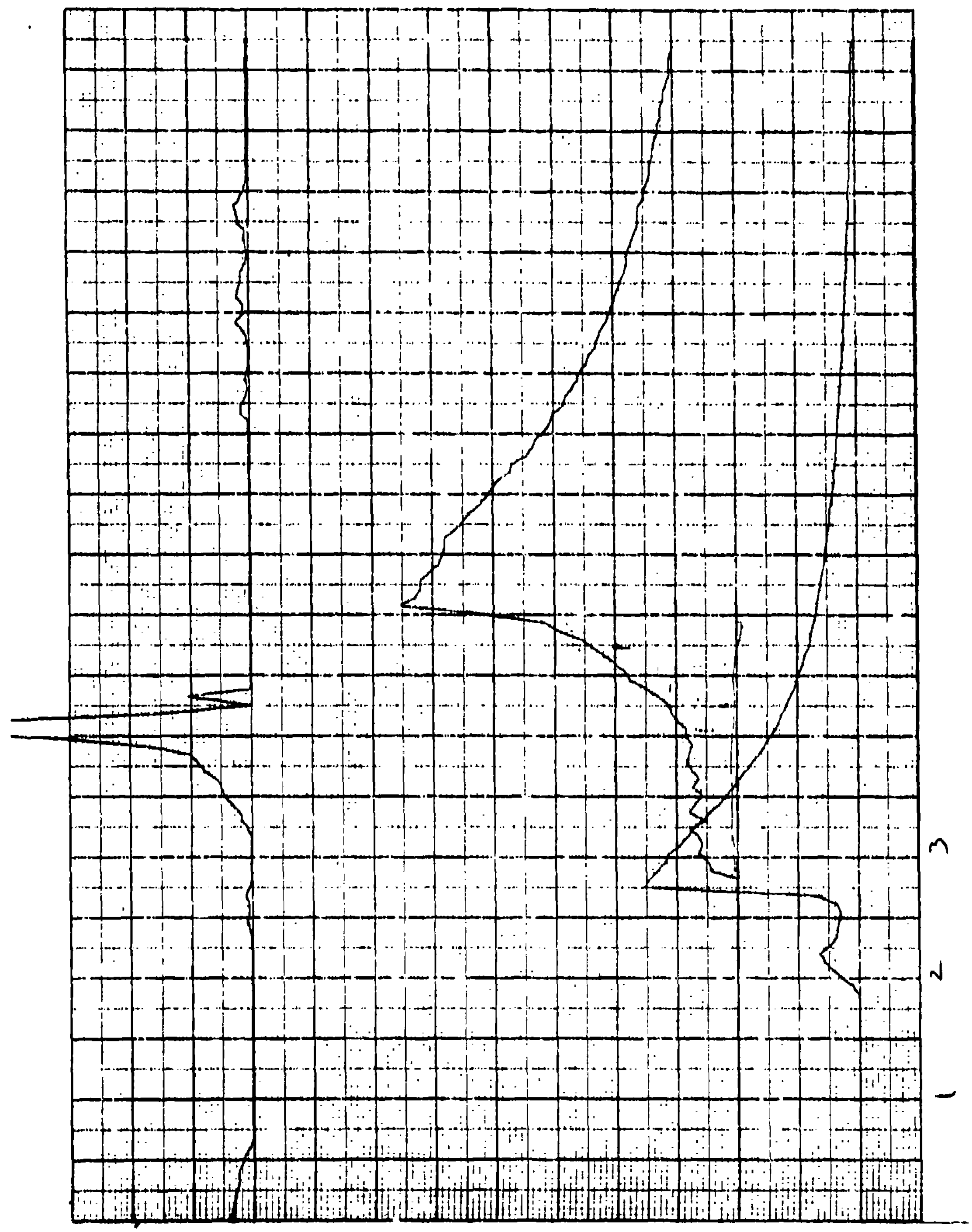


SECTION A-A

SEAL
25MM PLASTIC CASE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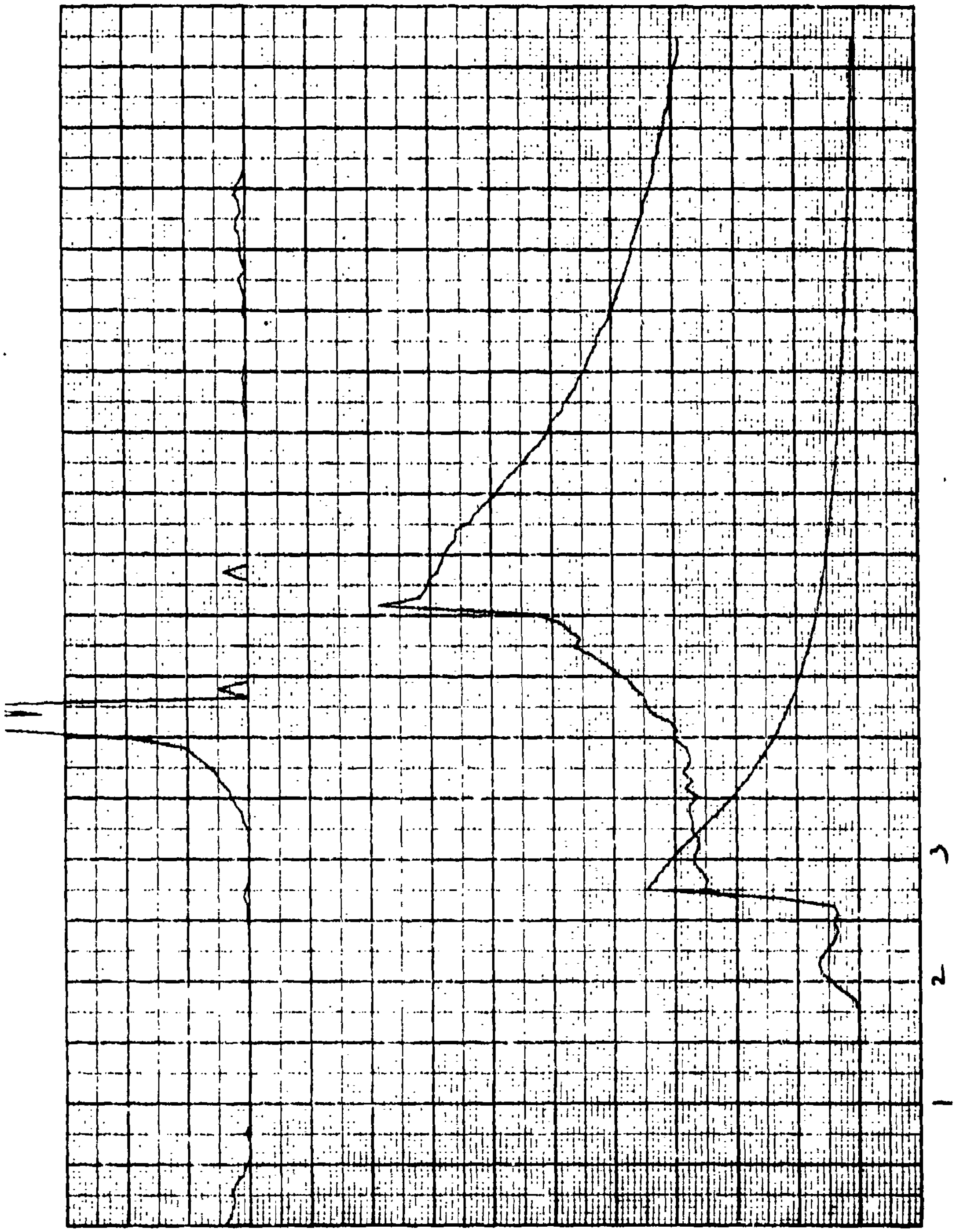

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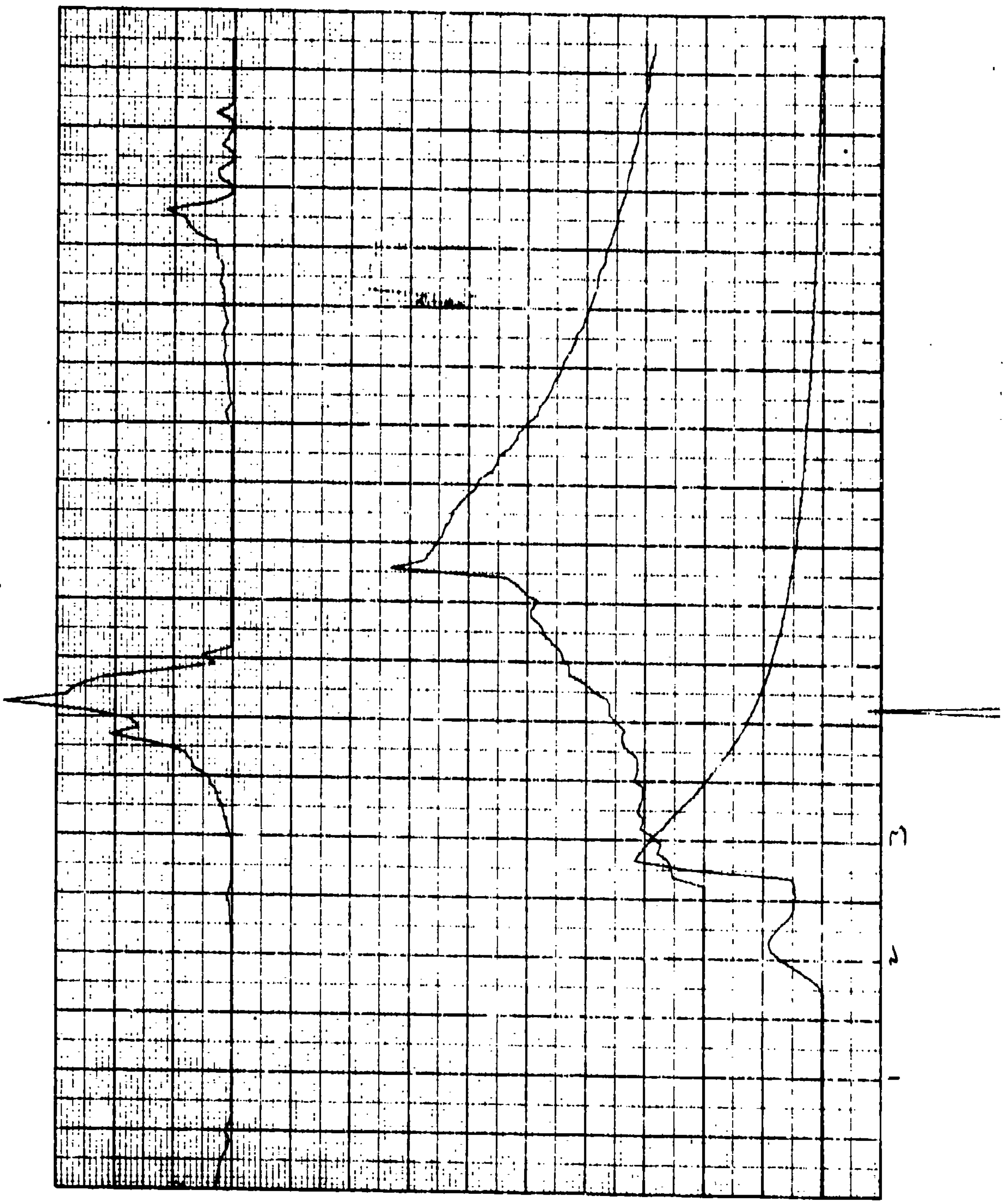
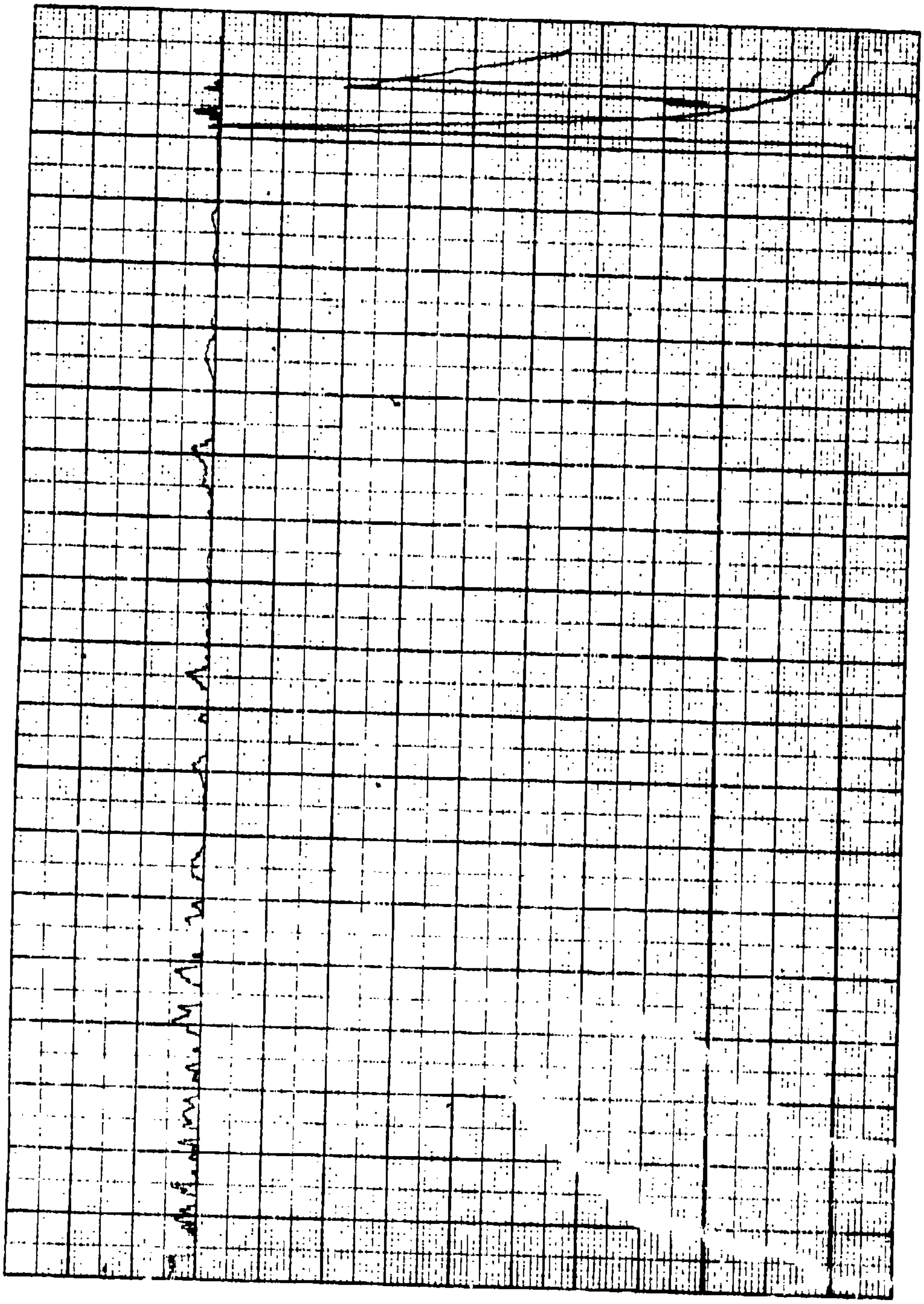
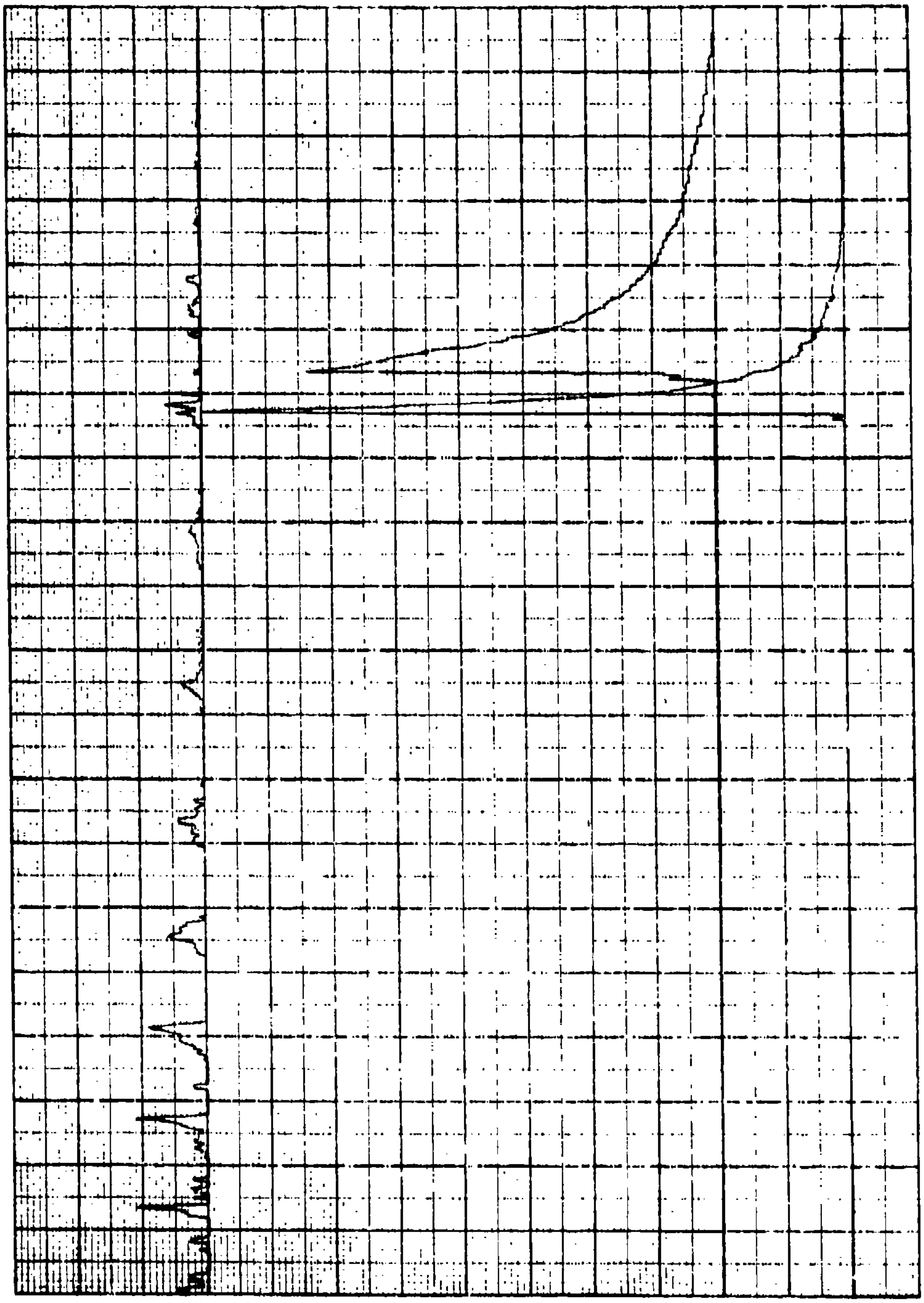






TEST REPORT

SERIAL NO. 12

OBJECTIVE: To evaluate the effect of aft charge surface deterrent on ballistic performance.

BACKGROUND: Selective surface deterrence studies were conducted in Phase III of the GAU-7/A program. Ballistic tests demonstrated the shot start cycle could be controlled with this technique. The coating utilized was a toluene thinned plastic rubber adhesive, No. PR-1 manufactured by Woodhill Chemical Corp. The rubber was painted on the surfaces of the charges to be deterred. GAU-7 tests indicated that the aft portion of the forware charge and the forward portion of the aft charge were critical ignition areas.

A reevaluation of the deterrent studies were considered to be beneficial to the development of the shot start mechanism in the plastic case cartridge. The rubber coating was applied to selected surfaces of several aft charges. The surfaces were the:

A. Ignitor cavity,
B. Ignitor cavity and the forward end,
C. Ignitor cavity, forward end and half the outside,
D. All surfaces.

Twelve rounds were assembled with:

Forward Charges	-	5479 Propellant
Aft Charges	-	8446-9 Propellant
Ignitor	-	TMS300432
Retention	-	40/10 NC/Mylar
Primer	-	32 S&W Pistol
Case	-	Nylon 12, 38 percent glass
Seal	-	ABS unfilled.

```
BALLISTIC
DATA:      F1 MAX     F2 MAX     F3 MAX     VELOCITY     TIME
           ------------------------------------------------
           ROUND NO--781         Hangfire


           ROUND NO--782
              34.5      -1.2       5.22       3455       44.67       TMS 300432
              0          0         0                                  0.15 gm
           LS1 TO LS2 3402
           F3 TO LS2 3428
           ROUND NO--783
              28.6      -.7        4.59                  26.4
              17.58      0         0
           LS1 TO LS2 2580
           F3 TO LS2 2959
           ROUND NO--784         Hangfire


           LS1 TO LS2
           F3 TO LS2
           ROUND NO--785         Hangfire

           ROUND NO--786
              48.2      -1.1       .94        2600       5.65         0.30 gm
              55.97      6         6
           LS1 TO LS2 1916
           F3 TO LS2 2572
           ROUND NO--787
              62        -.5        4.34       3097       5.32
              69.26      0         1.03
           LS1 TO LS2 3017
           F3 TO LS2 3057
           ROUND NO--788
              49.4      -.1        5.91       2600       4.7
              67.75      0         4.3
           LS1 TO LS2 1776
           F3 TO LS2 2624
           ROUND NO--789
              57.6      -.1        4.1        2800       5.16
              69.61      0         4.25
           LS1 TO LS2 1951
           F3 TO LS2 2794

           ROUND NO--790
              61.2      -.4        5.1        3161       5.32
              68.71      0         .89
           LS1 TO LS2 3243
           F3 TO LS2 3175
           ROUND NO--791
              58.8      -.3        5.18       3161       4.91
              69.47      0         .99
           LS1 TO LS2 3243
           F3 TO LS2 3175
           ROUND NO--792
              55.4      -.2        4.86       2970       5.18
              69.76      0         1.96
           LS1 TO LS2 3069
           F3 TO LS2 2987
```

DISCUSSION: The cartridges were originally assembled with 0.15 gram of ignitor TMS300432. Ballistic action times recorded with rounds No. 81 to 85 were not less than 26 milliseconds (msec). The latter value exceeded the sampling time for the data acquisition system and no data was recorded. The remaining ignitors were down loaded and the ignitor charge was increased to 0.30 gram. The action times for the subsequent tests averaged 5 milliseconds and resulted in blowby performance. The magnitude of the blowby pressure was approximately half the pressure normally observed without the deterrent coating. The magnitude of the blowby pressure was not reduced sufficiently to provide the desired ballistic performance. The most uniform performance was observed with all the surfaces of the aft charge coated.

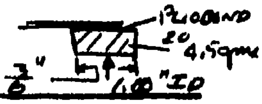
CONCLUSION: Surface deterrence of the aft charge had a beneficial effect on the ballistic performance by reducing the magnitude of blowby. The TMS300432 ignitor was too brisance for the preliminary evaluation. Subsequent tests with deterred charges should use a black powder ignitor.

25MM PLASTIC CASE
AMMUNITION DEVELOPMENT

S/N. 12
DATE: 29 JULY 74
ENGR: CARY
AMMO: CATTON/BURNETT

OBJECTIVE: TO OBSERVE THE EFFECT OF AFT CHARGE SURFACE DETERRENTS ON BALLISTIC PERFORMANCE

Test Fixture: IITRI, UNIVERSAL, RIA.
Cartridge Case: Dwg. No. SK 100460, Rev.____, Mat'l NYLON 12, 30% GLASS
Dwg. No. ________, Rev.____, Mat'l________.
Projectile: Dwg. No. 300347, Rev. A, Plastic Band, 3000 Grain.
Primer: Type A5102, Lot No.________, No.________.
Flash Tube: 32510, 38 Special, ________.
I3150 BONDED BOTH
Projectile Retention: 40 Mil NC, 10 Mil Mylar, ________ GRAMS
Ignitor: THS 300432, Seals: ABS – AS SHOWN
Propellant: Fwd Charge 5479, Lot No. 7-22.
Aft Charge 8446-9, Lot No. 7-19.
Insert N/A, Lot No.________.

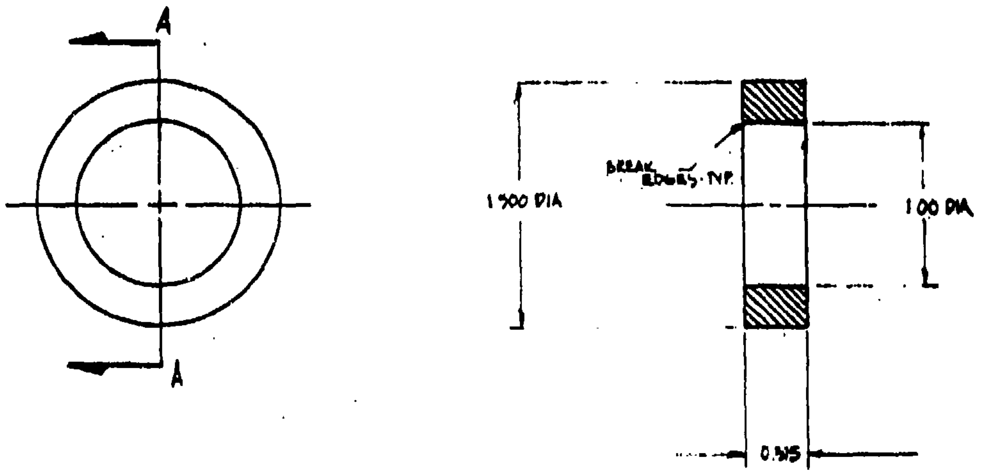


REMARKS: DETERRENT MADE BY THINNING DURO PLASTIC RUBBER WITH TOLUENE – APPLIED WITH PAINT BRUSH TO SURFACES SHOWN IN MARGIN

RD. LENGTH 6.075 / 6.085 (0.020 / 0.030 INCH CRUSH G/P.)

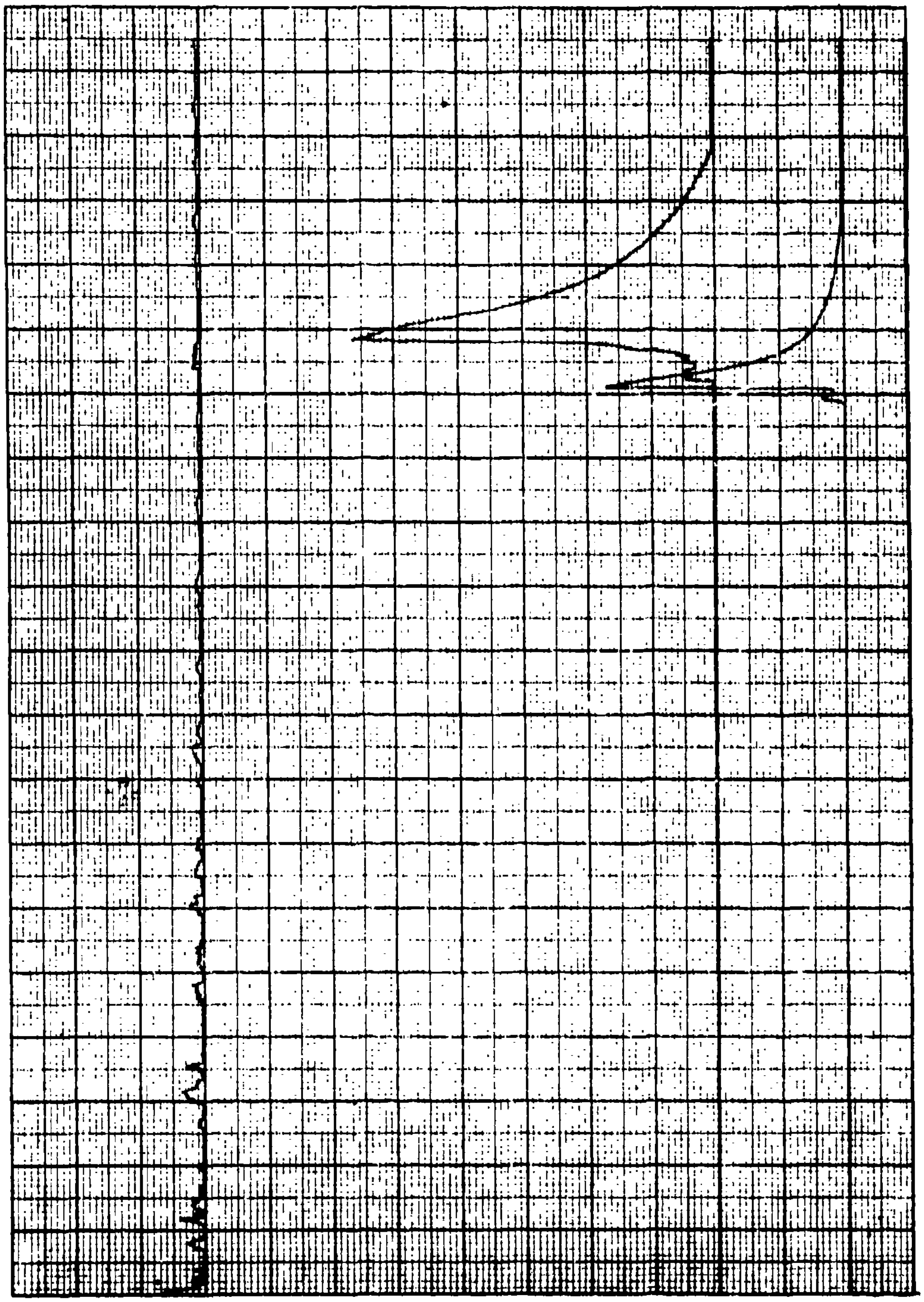
ROUND NO.	PROPELLANT WT (GRAMS)			TOTAL PROP. WT	IGNITOR WT
	FWD	AFT	INSERT	(GRAMS)	THS (GRAMS) 432
81	90.9	44.6	—	135.5	0.15
82	91.6	44.8	—	136.4	0.15
83	91.1	44.6	—	135.7	0.15
84	91.2	44.5	—	135.7	0.15
85	90.9	44.9	—	135.8	0.15
86	92.2	44.6	—	136.8	0.30
87	91.4	44.6	—	136.0	0.30
88	90.5	44.7	—	135.2	0.30
89	92.0	44.6	—	136.6	0.30
90	91.0	44.5	—	135.5	0.30
91	90.9	44.9	—	135.8	0.30
92	90.6	44.3	—	134.9	0.30

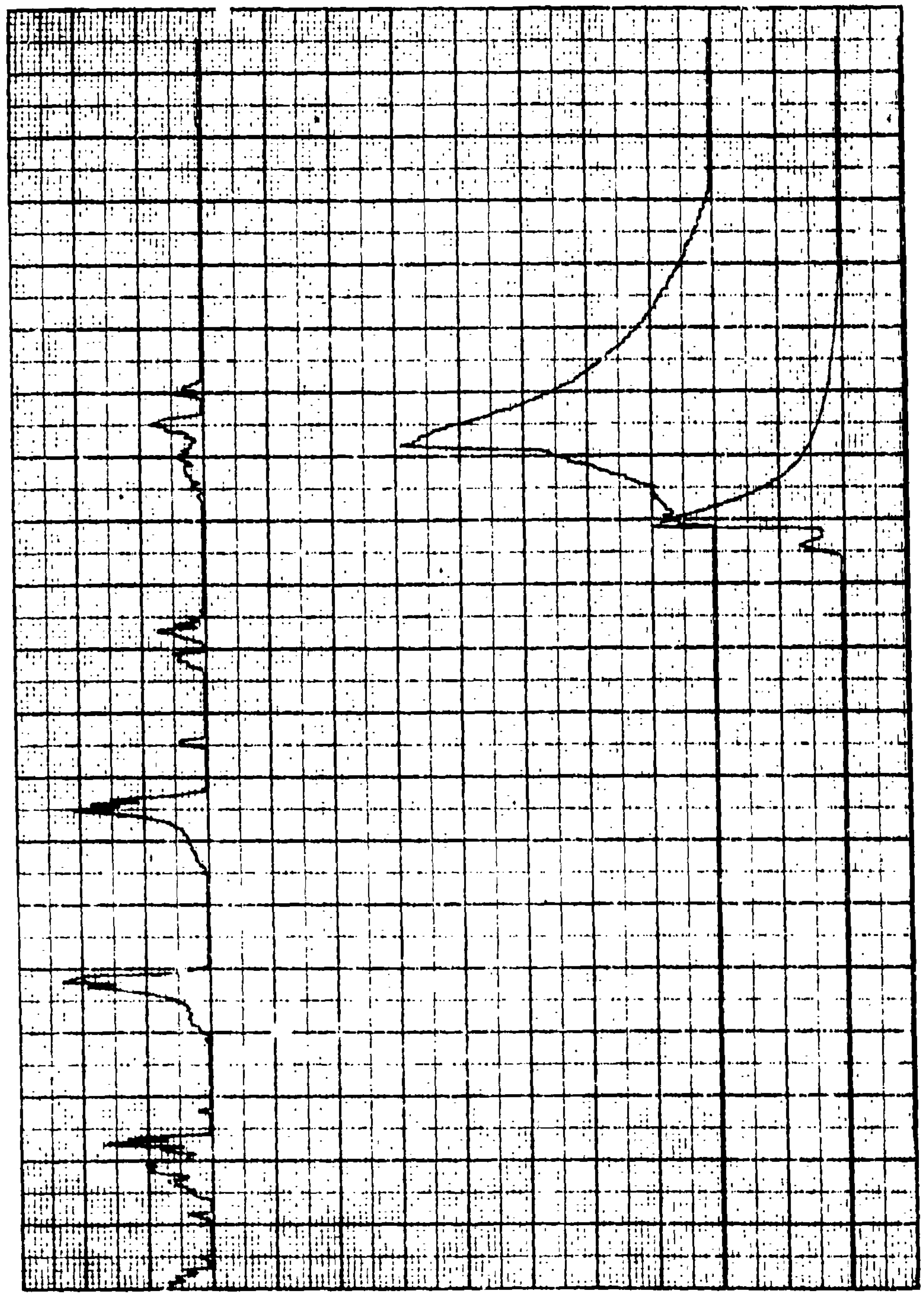
FORM NO. SG-555-81

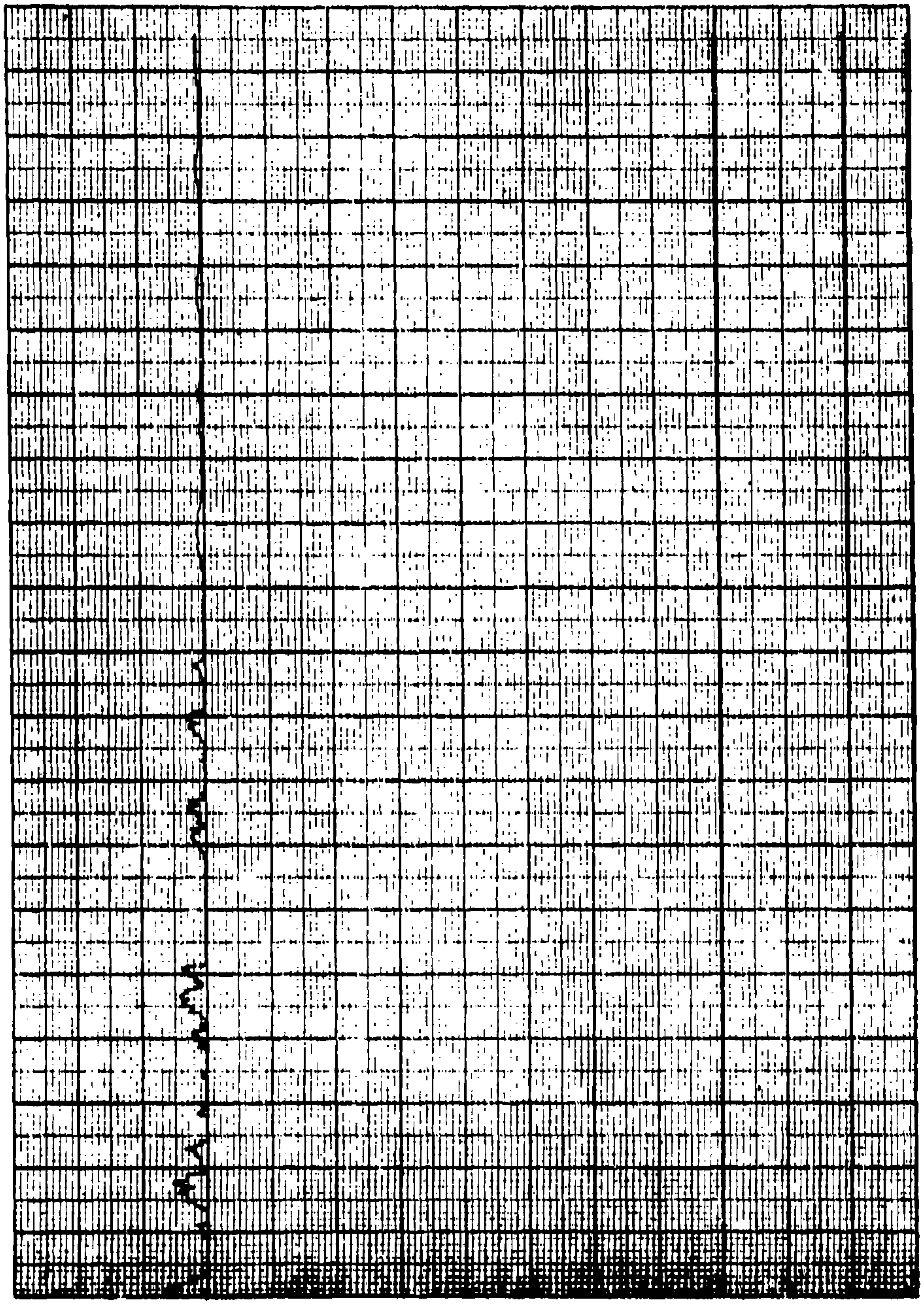


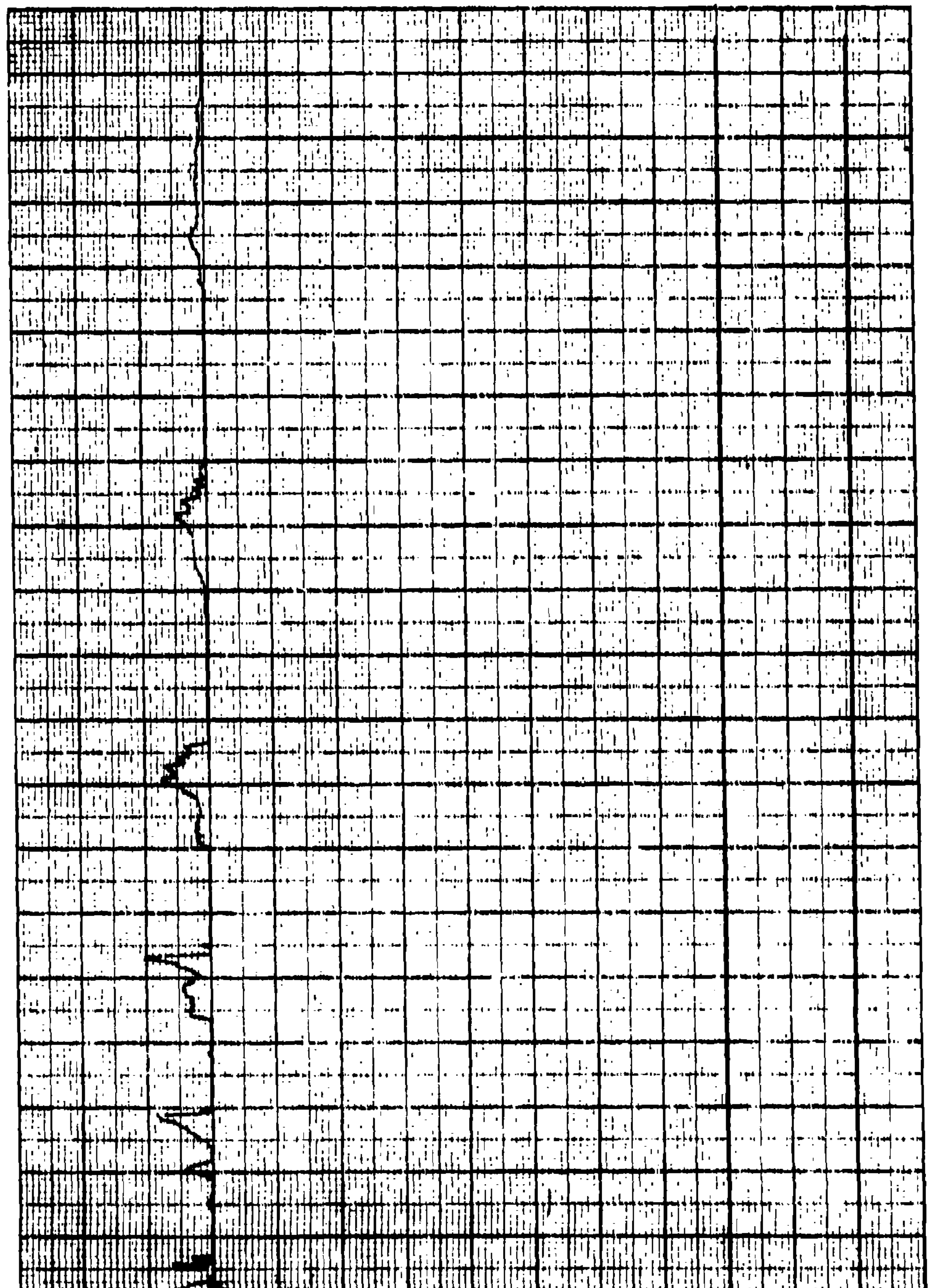
SECTION A-A

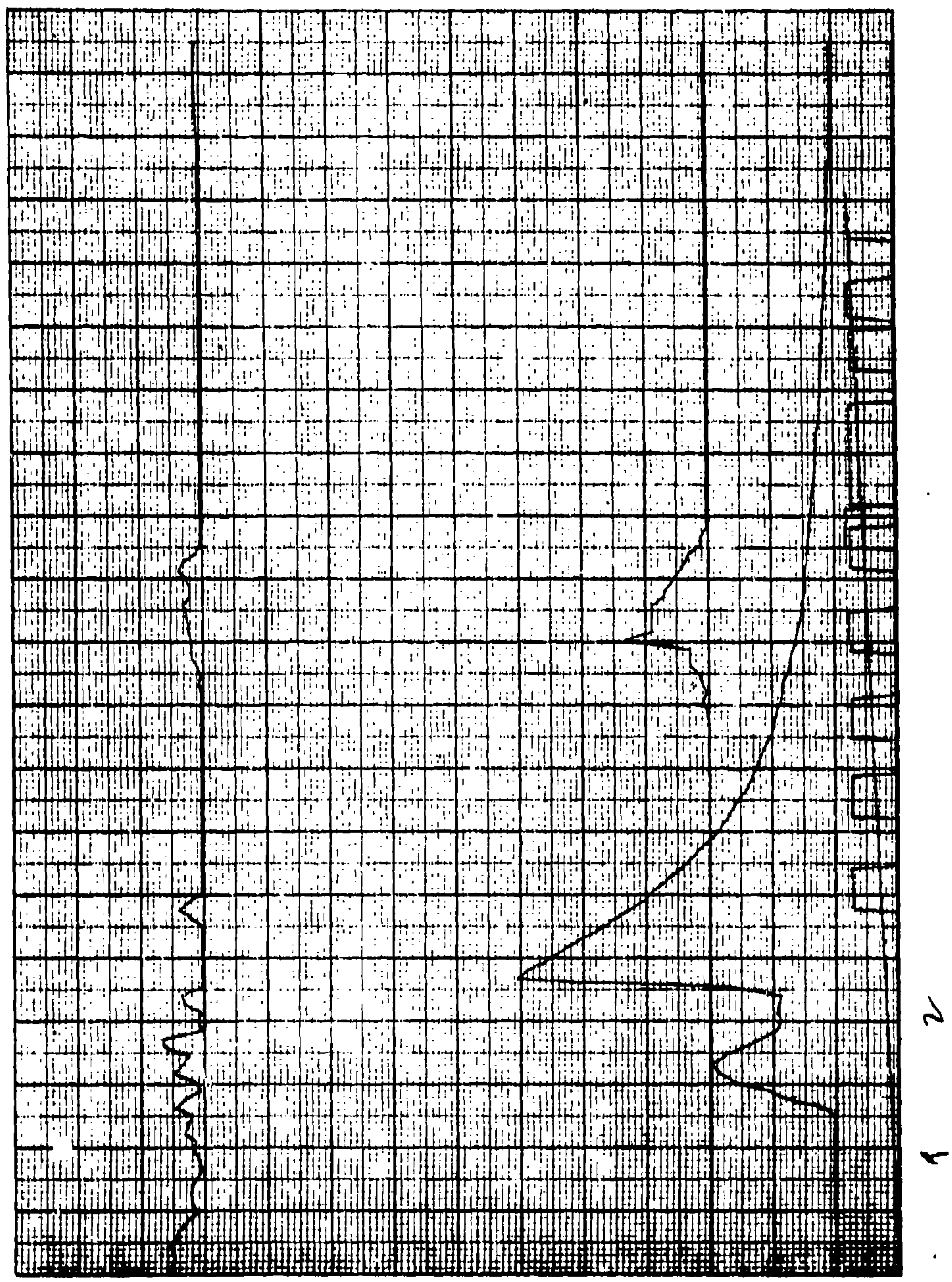
SEAL
25MM PLASTIC CASE











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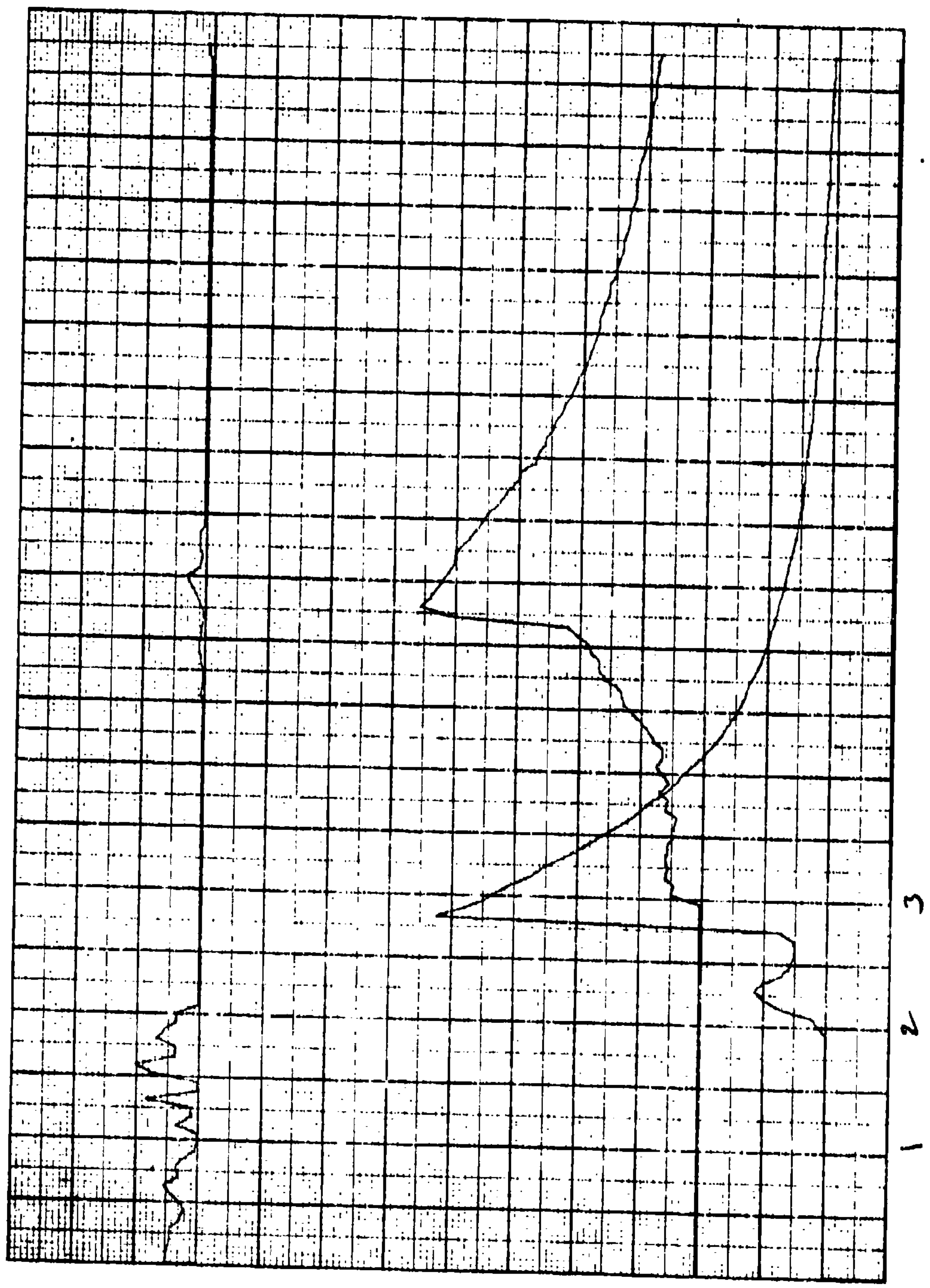
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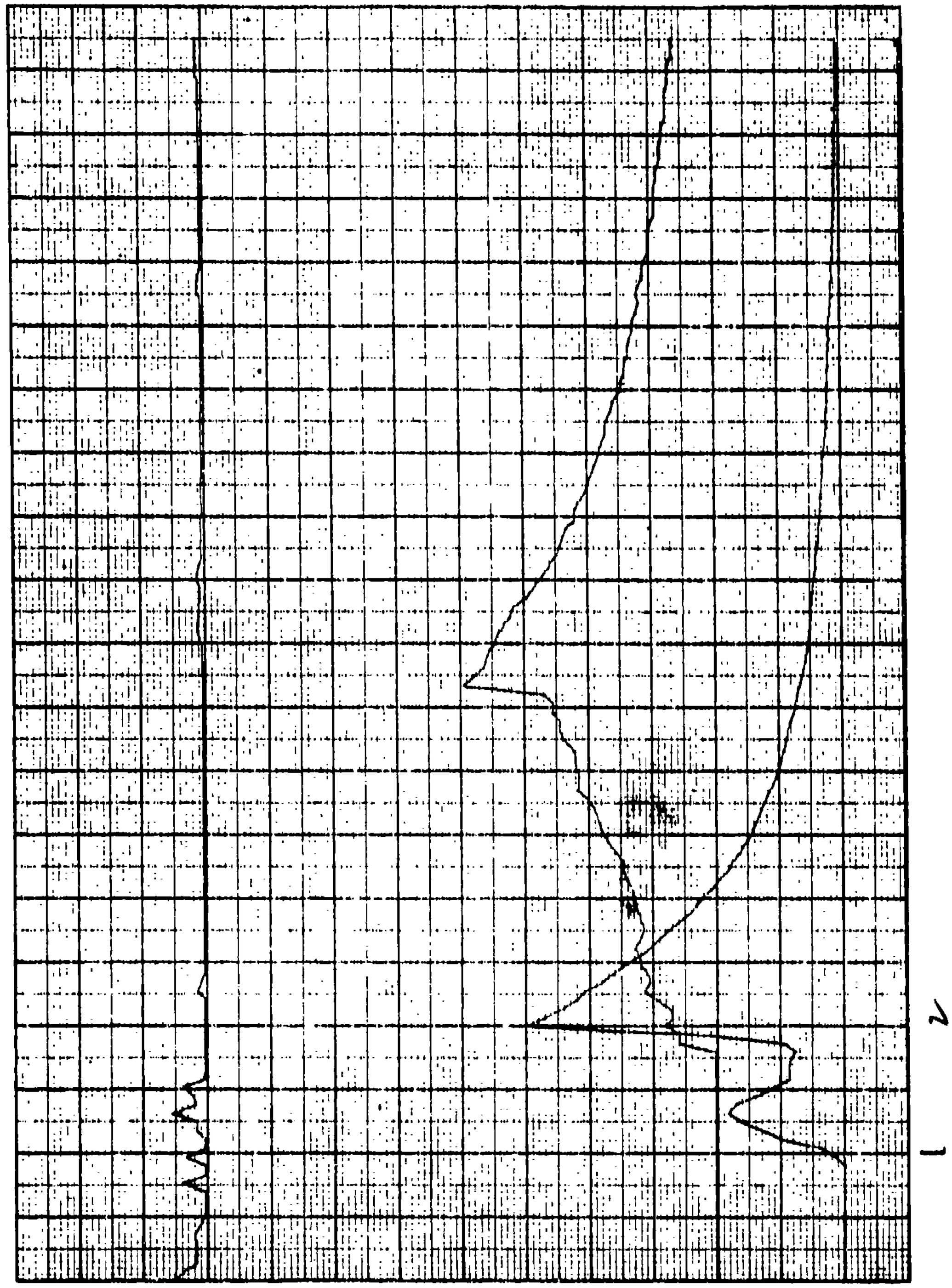
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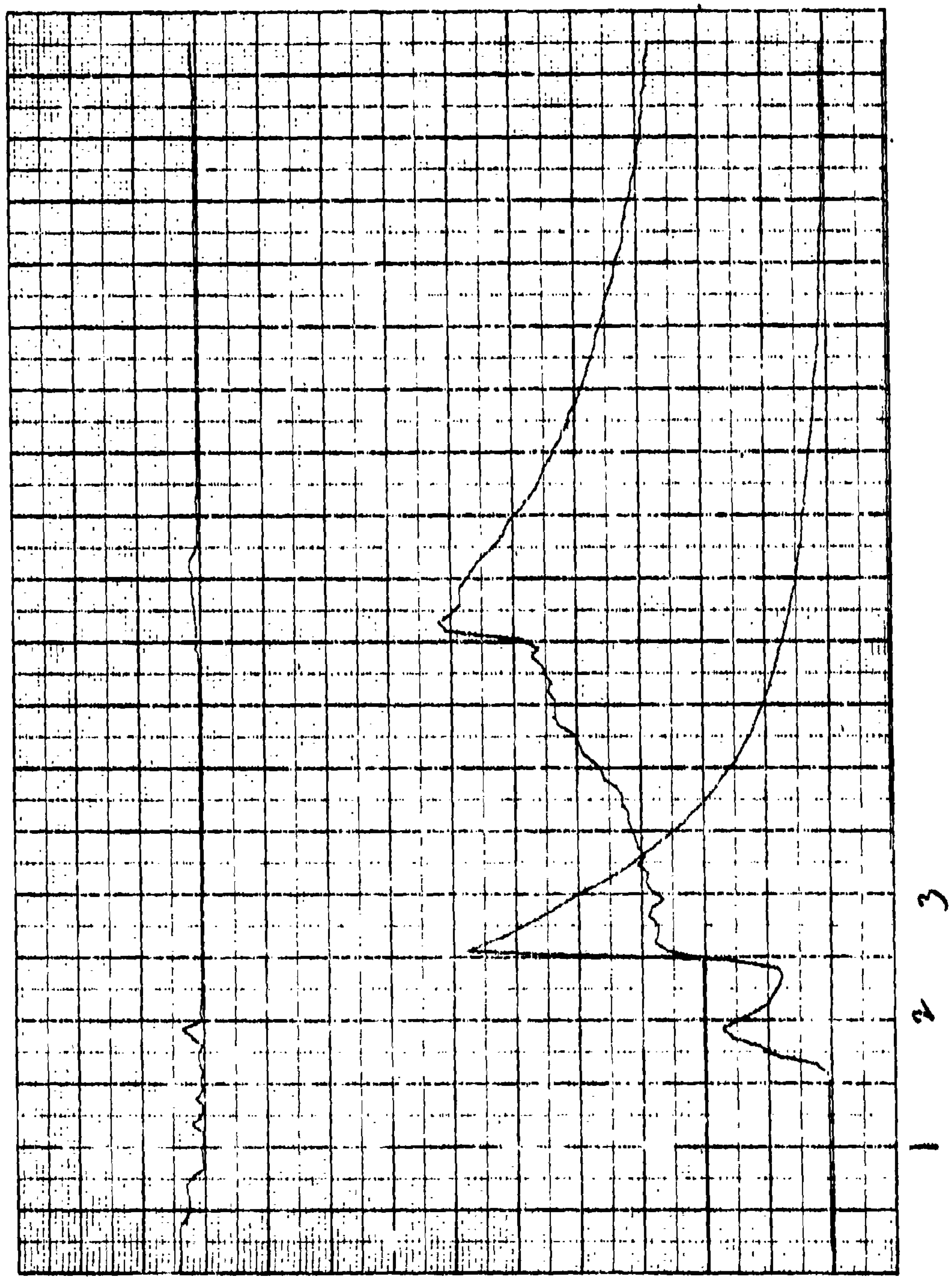
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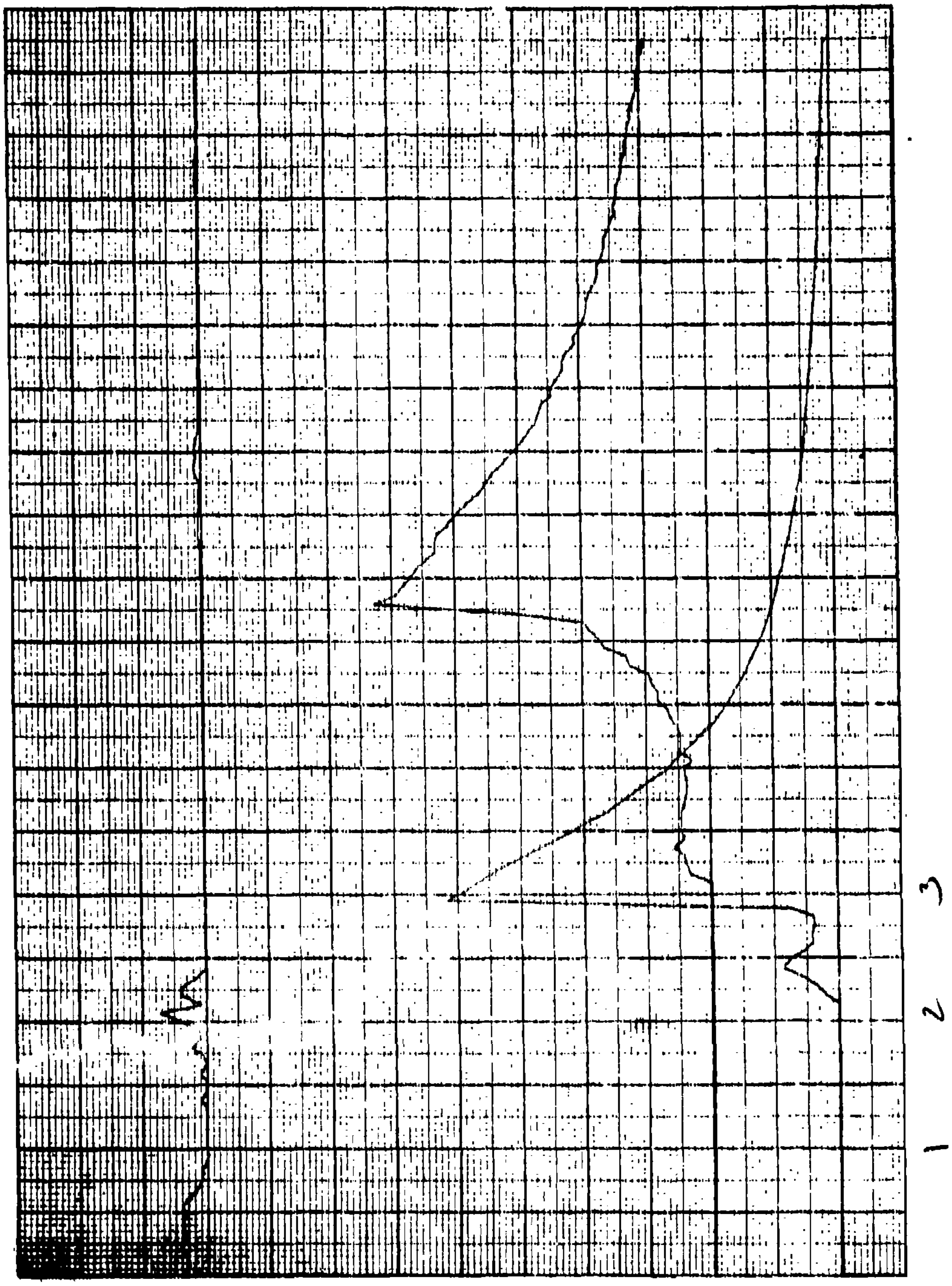
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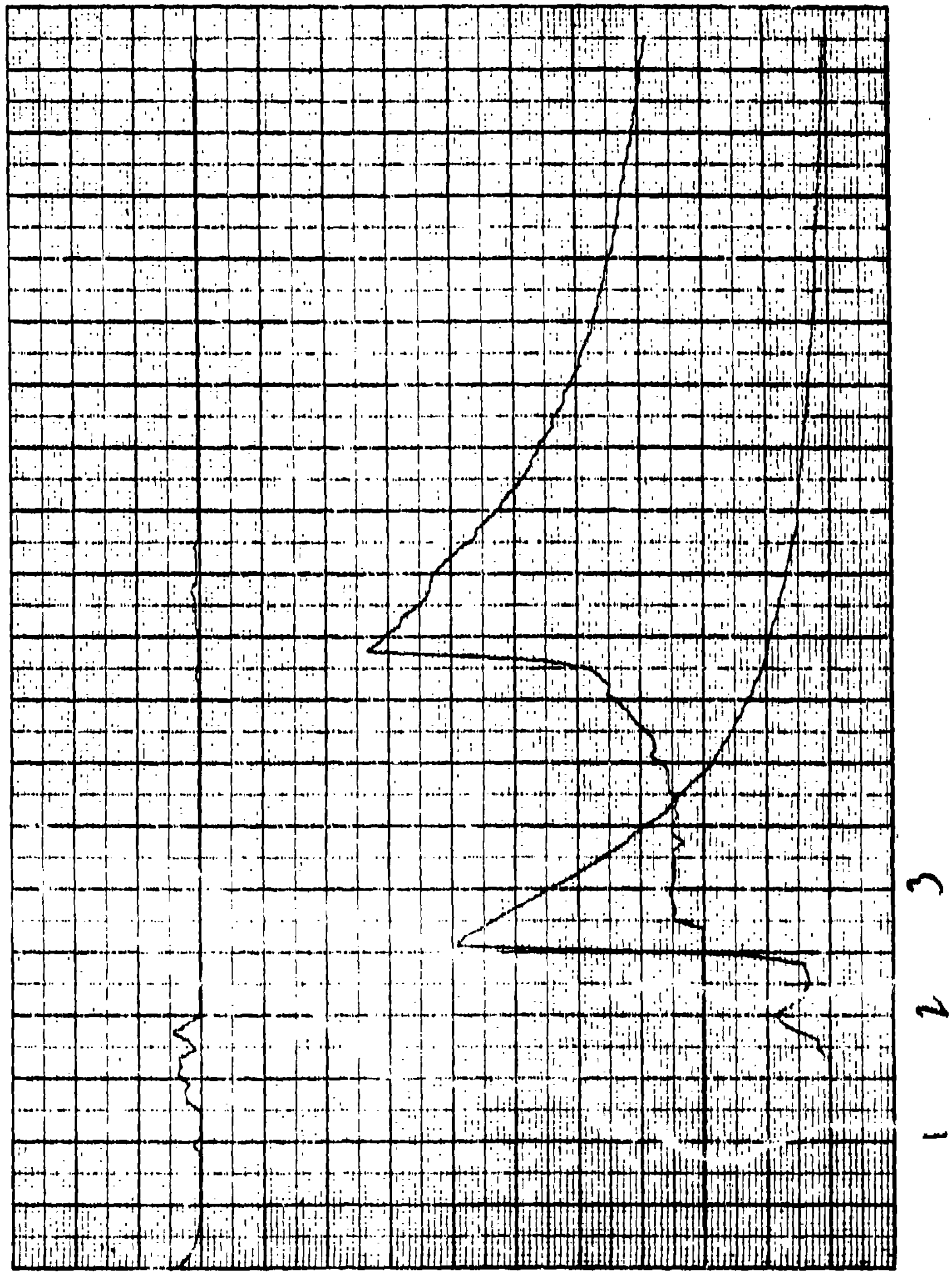
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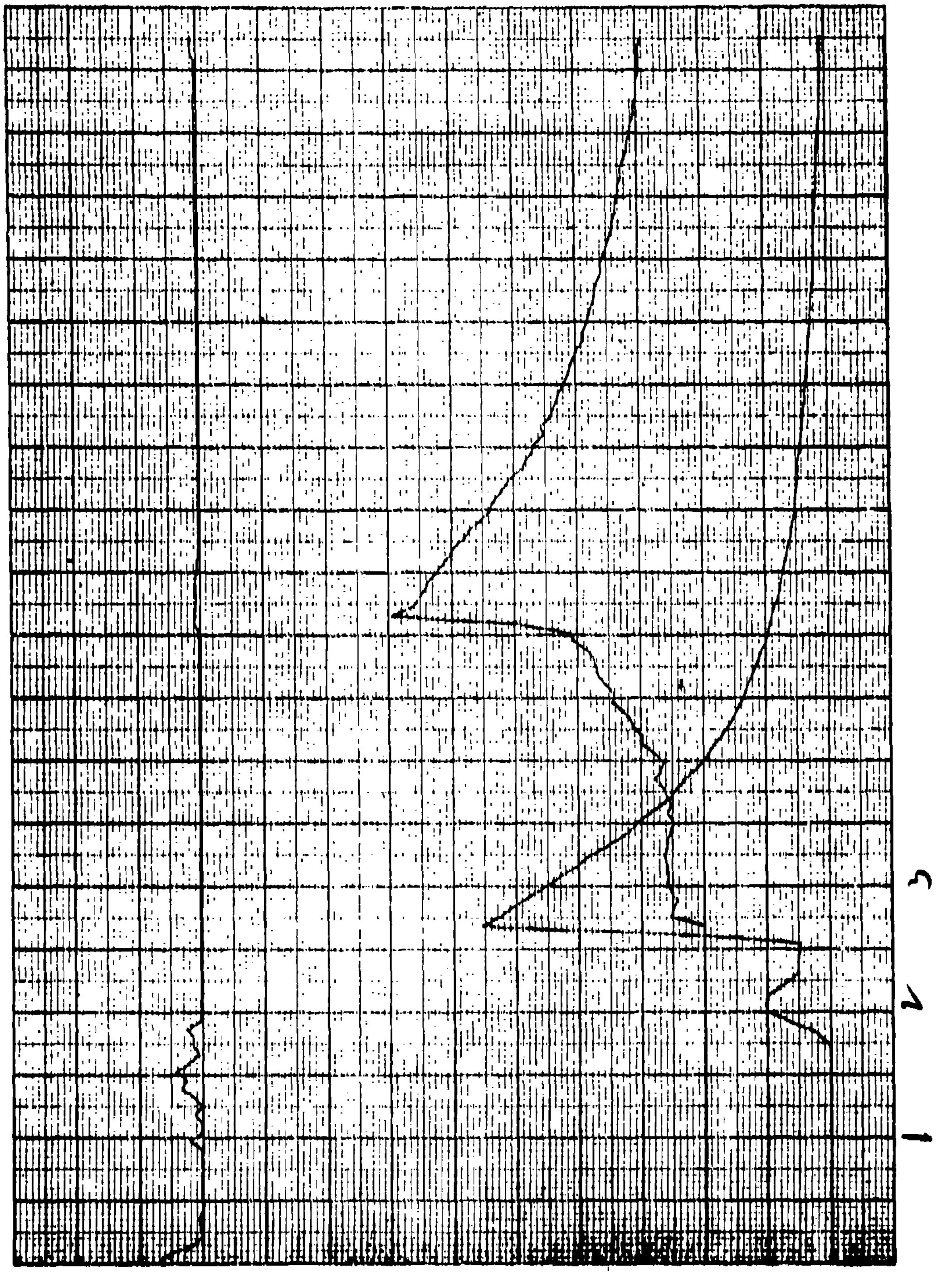
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TEST REPORT

SERIAL NO. 15

OBJECTIVE: To select a baseline black powder ignitor for surface deterred aft charges.

REFERENCE: S/N 12

BACKGROUND: The tests conducted in Series S/N 12 with selectively deterred aft charge surfaces indicated the ignitor TMS300432 was too brisant. A black powder ignitor was recommended subsequent to preliminary evaluations.

Black powder granulations Class 3 and 6 were selected for these tests. The black powder was identified per MIL-P-223. The aft charges were painted with the neoprene deterrent on all surfaces.

Ten rounds were assembled with:

Forward Charge	-	5479 Propellant
Aft Charge	-	8446-9 Propellant
Ignitor	-	Black Powder, Class 3 and 6
Retention	-	40/10 NC/Mylar
Primer	-	32 S&W Pistol
Case	-	Nylon 12, 38 percent glass
Seal	-	ABS, unfilled

```
BALLISTIC
DATA:        P1 MAX      P2 MAX     P3 MAX     VELOCITY    TIME
             ------------------------------------------------------
             ROUND NO--?99
                58          -.8        4.32       3357       5.53     BP Class 6
                49.55       0          7.04
             LS1 TO LS2 1698
             P3 TO LS2 2869
             ROUND NO--?100
                58.7        -.2        5.1        2730       6.08
                62.37       0          8.46
             LS1 TO LS2 2770
             P3 TO LS2 2737
             ROUND NO--?101
                38.2        .1         3.78       1669       13.49
              .083
                45.39       1.19       7.12
             LS1 TO LS2 1864
             P3 TO LS2 1700




             ROUND NO--? 102
             ?102
                99.1        .2         5.72       3833       7.18     BP Class 3
                75.04       1.38       4.07
             LS1 TO LS2 3781
             P3 TO LS2 3824
             ROUND NO--?103
                88.7        .3         4.98       3199       6.56
                64.12       1.21       7.49
             LS1 TO LS2 3243
             P3 TO LS2 3206
             ROUND NO--?104
                40.6        .3         3.85       2526       8.62
                50.4        2.36       10
             LS1 TO LS2 1405
             P3 TO LS2 2216
             ROUND NO--?105
                37.7        .3         4.26       2650       7.18
                37.5        2.2        6.52
             LS1 TO LS2 1777
             P3 TO LS2 2441
             ROUND NO--?106
                99.9        .3         6.07       3860       7.31
                81.41       2.29       4.93
             LS1 TO LS2 3910
             P3 TO LS2 3869
```

DISCUSSION: Black powder Class 6 was evaluated in rounds No. 99, 100 and 101. The test results indicated that Class 6 was not a satisfactory ignitor. All the charges produced blowby performance. The incorporation of a mylar strip inside the aft grain increased the ignition delay and delayed the retainer release resulting in a long action time and violent blowby.

The decision was made to evaluate the remainder of the rounds with Class 3 black powder. An ignitor charge weight of 0.75 gram was evaluated in Test No. 102. The resultant ballistic performance indicated that this cartridge had a satisfactory shot start cycle but the 99 Kpsi pressure indicated that the projectile stopped or hesitated at the barrel. A repeat test at 0.75 gram charge resulted in similar high pressure performance but blowby reduced the velocity to 3200 fps. A reduction in charge weight to 0.60 gram produced a similar effect as a reduced charge weight of the Class 6 did on performance. The action time increased slightly and the velocity decreased. This behavior was indicative of a projectile stop prior to barrel obturation -- a situation observed in the GAU-7 shot start development program. The behavior is a result of insufficient ignitor energy to propel the projectile and ignite the propellant at the correct time in the shot start sequence of events. A test with the mylar strip has similar low performance results due to delayed projectile first motion (late retainer release).

The forward seals were ejected from the test fixture.

CONCLUSION: Class 3 black powder was selected as a baseline ignitor for deterred surface experiments. The charge weight recommended was 0.75 $\pm$ 0.05 gram.

The cuase for the excessive chamber pressures was the result of stop mode performance. The propellant RQ selected for this cartridge was based on nonstop GAU-7 ballistics.

25MM PLASTIC CASE
AMMUNITION DEVELOPMENT

S/N: 15
DATE: 21 AUG 74
ENGR: CARY
AMMO: CATRON-BURLETT

OBJECTIVE: TO SELECT A BASELINE BLACK POWDER IGNITOR FOR SURFACE DETERRED AFT CHARGES.

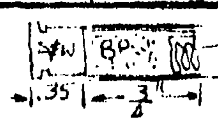
Test Fixture: IITRI, UNIVERSAL, RIA.
Cartridge Case: Dwg. No. SK 300460, Rev.____, Mat'l NYLON 12, 38% GLASS
Dwg. No. ________, Rev.____, Mat'l________.
Projectile: Dwg. No. 300347, Rev. A, Plastic Band, 3000 Grain.
Primer: Type PISTOL, Lot No.________, No.________.
Flash Tube: 3256B 38 Special, ________.
Projectile Retention: 40 MIT NC, 10 Mil Mylar, ________ [redacted] ________ IS/50 BOND FWD GRAIN & AFT GRAIN
Ignitor: BP CLASS 3 ??, Seals: ABS
Propellant: Fwd Charge 5479, Lot No. 7-19.
UNK Aft Charge 5446.9, Lot No. 7-19.
Insert________, Lot No.________.

REMARKS: AFT CHARGES - ALL SURFACES PAINTED NEOPRENE BASE DETERRENT

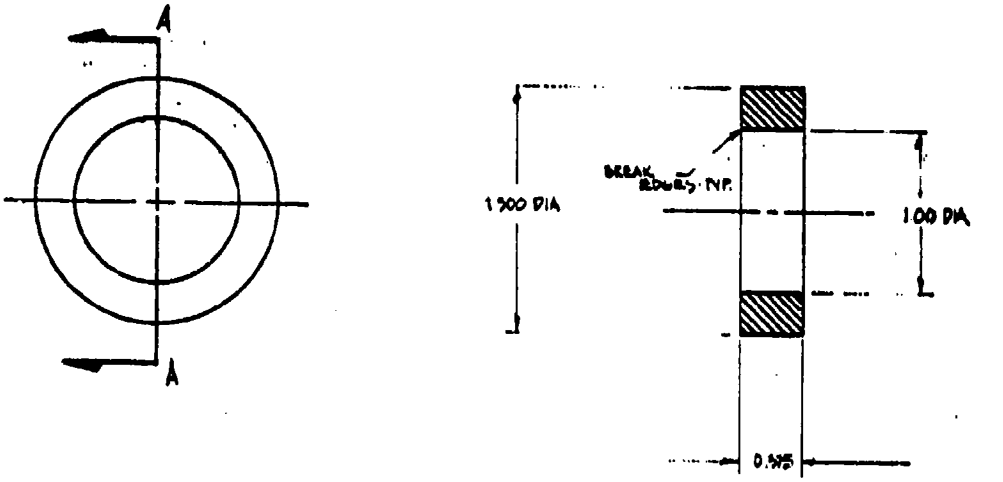
RD. LENGTH 6.075 / 6.085 (0.029 / 0.030 IN CAUSA ??)

ROUND NO.	PROPELLANT WT (GRAMS) FWD	AFT	INSERT	TOTAL PROP. WT (GRAMS)	IGNITOR WT (GRAMS)
					BP (6)
99	91.2	46.0	—	137.2	0.75
100	91.2	46.0	—	137.2	0.50
101	91.2	46.0	—	137.2	0.50 @ MYLAR B
					BP (3)
102	91.2	46.0	—	137.2	0.75
103	91.2	46.0	—	137.2	0.75
104	91.2	46.0	—	137.2	0.60
105	91.2	46.0	—	137.2	0.75 @ MYLAR A
106	91.2	46.0	—	137.2	0.70
107	91.2	46.0	—	137.2	NOT FIRED
108	91.2	46.0	—	137.2	NOT FIRED

A

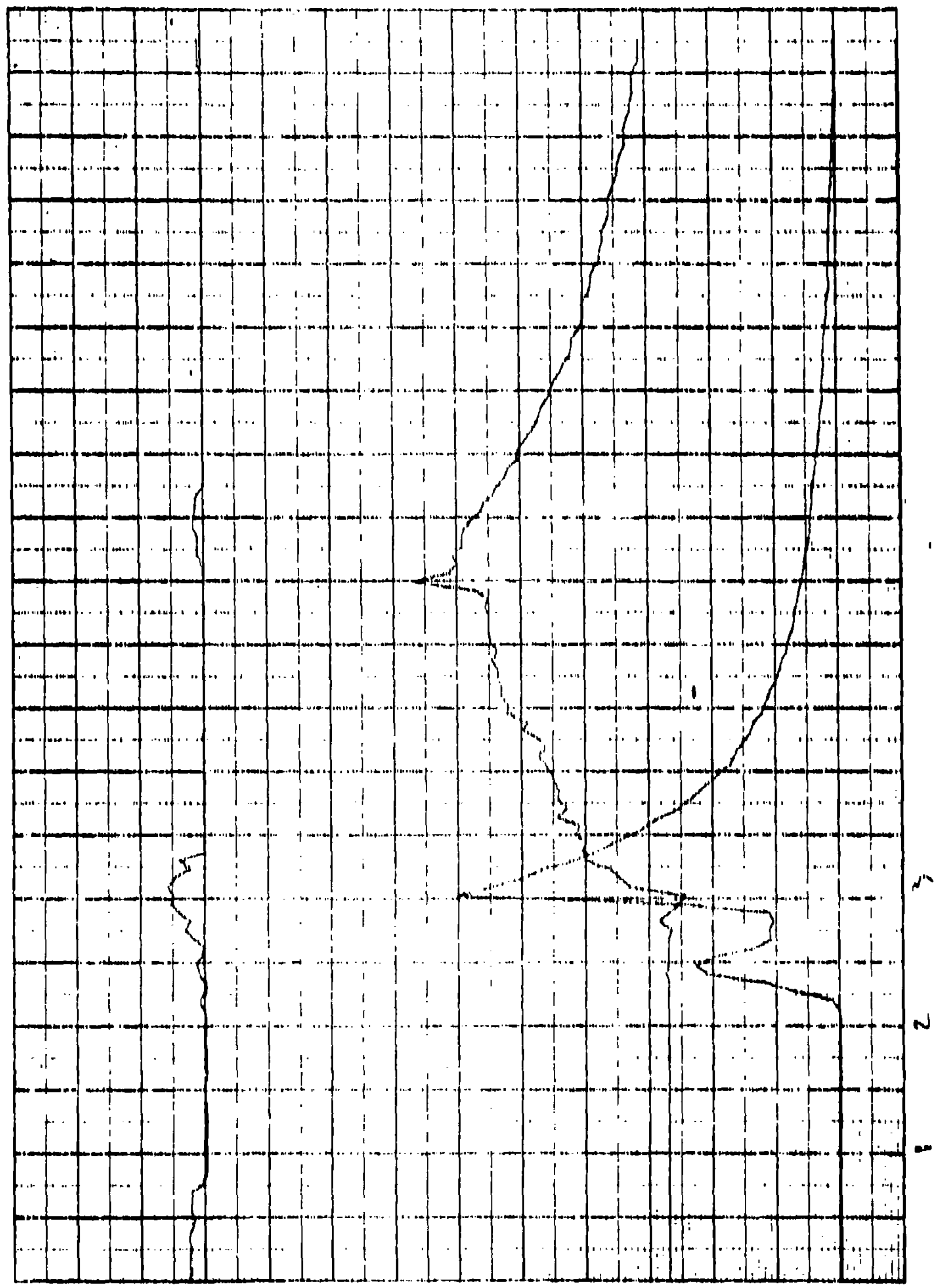


FORM NO. SG-555-81



SECTION A-A

SEAL
25MM PLASTIC CASE



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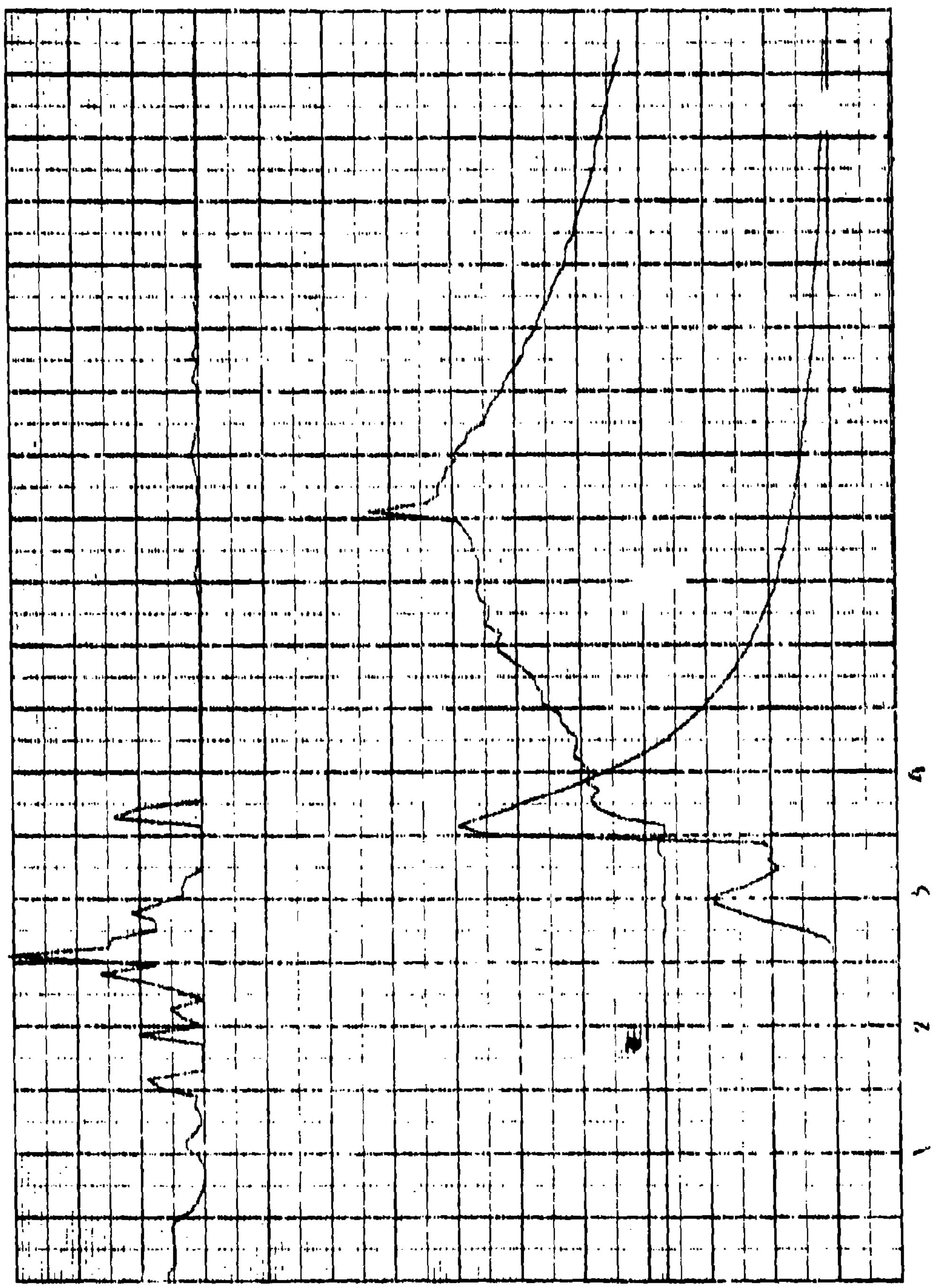

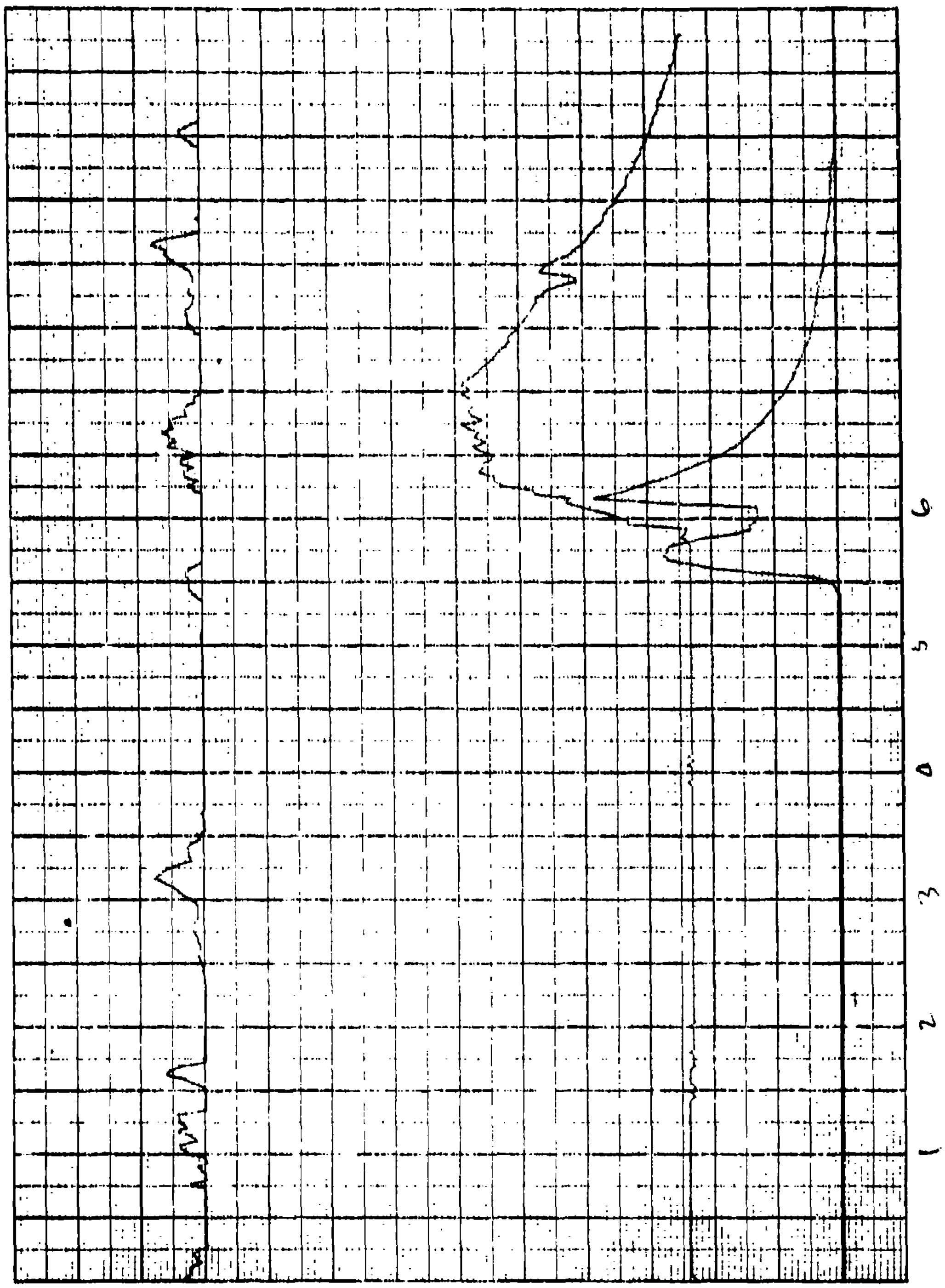
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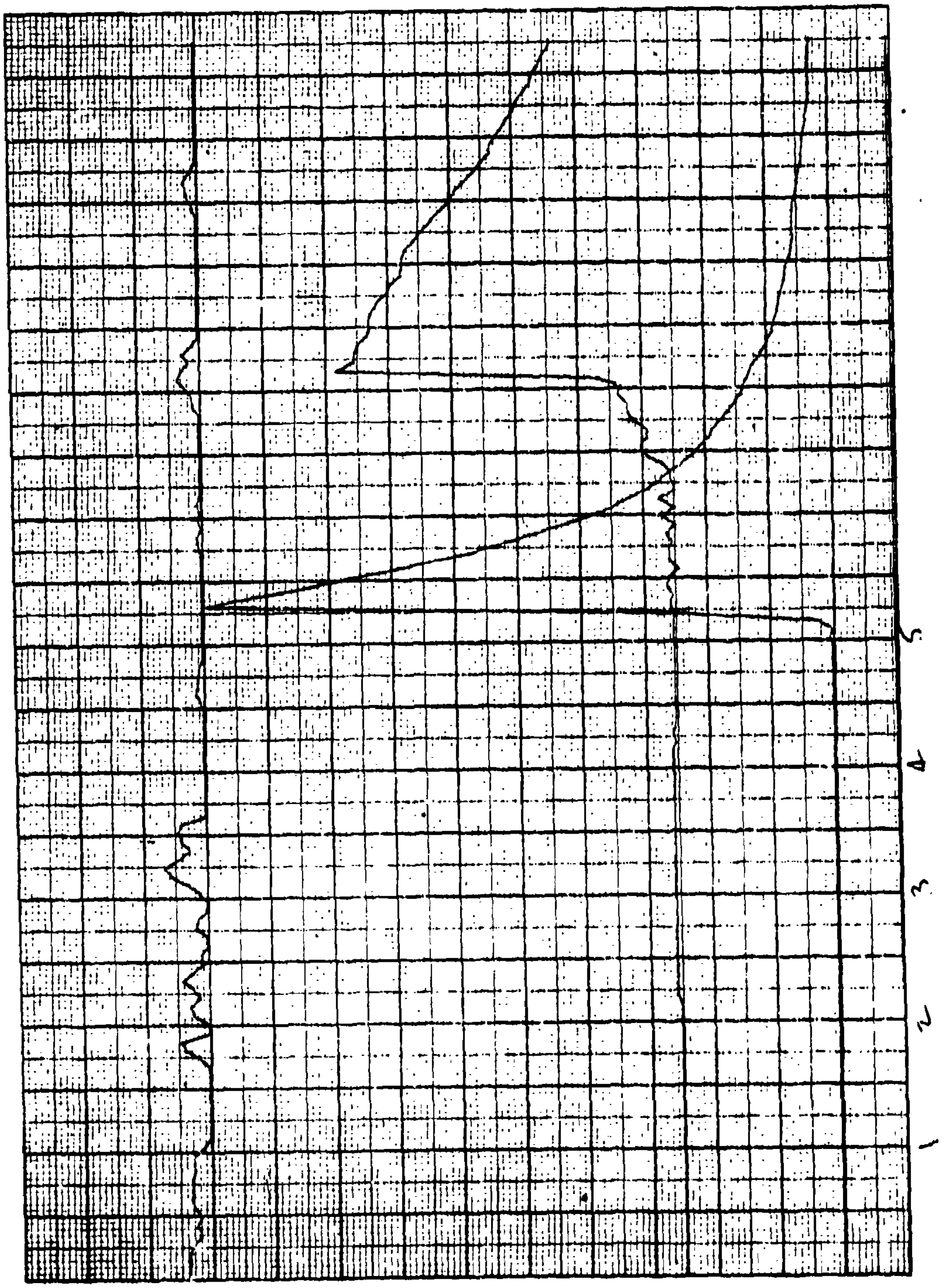

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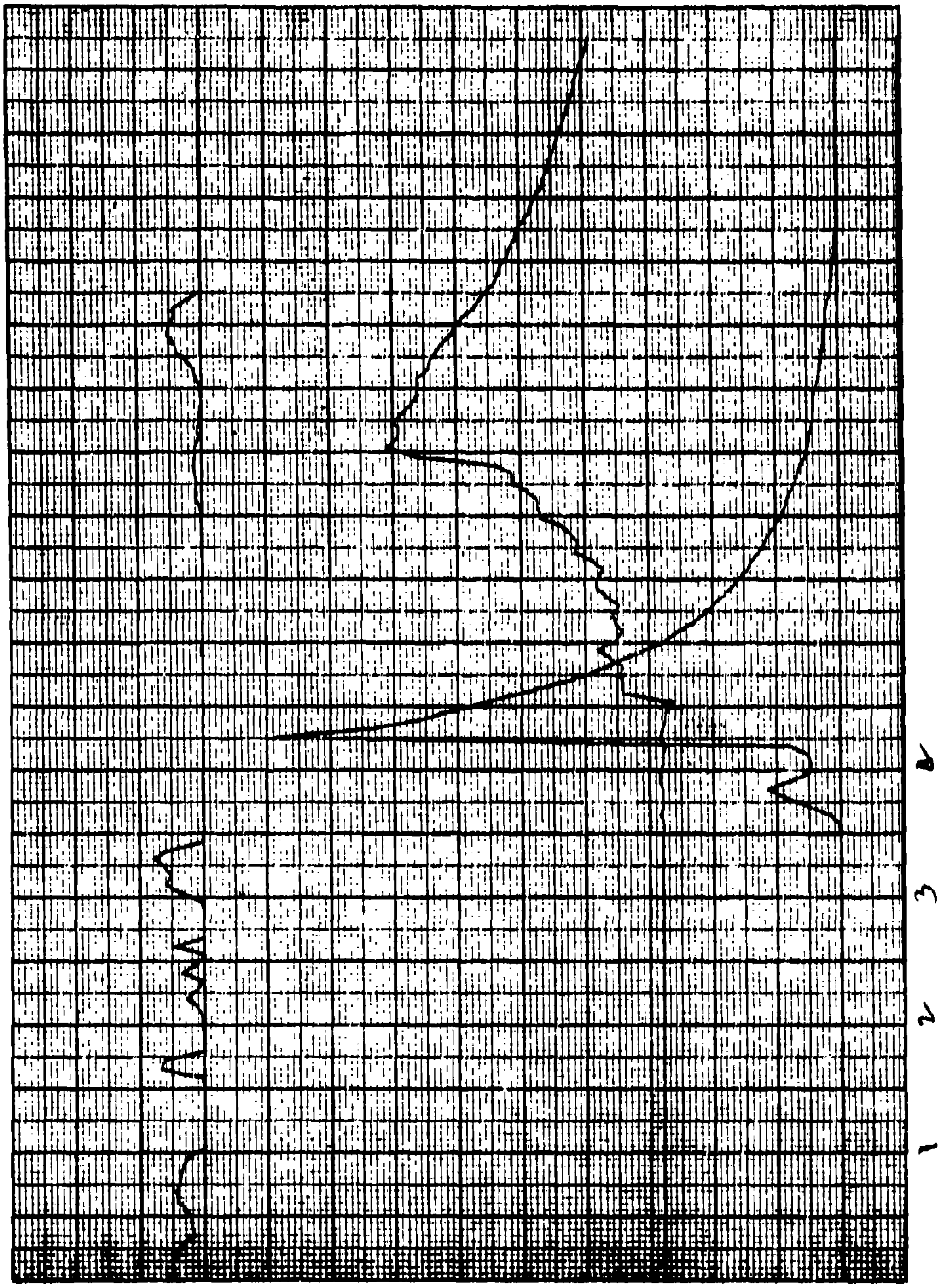
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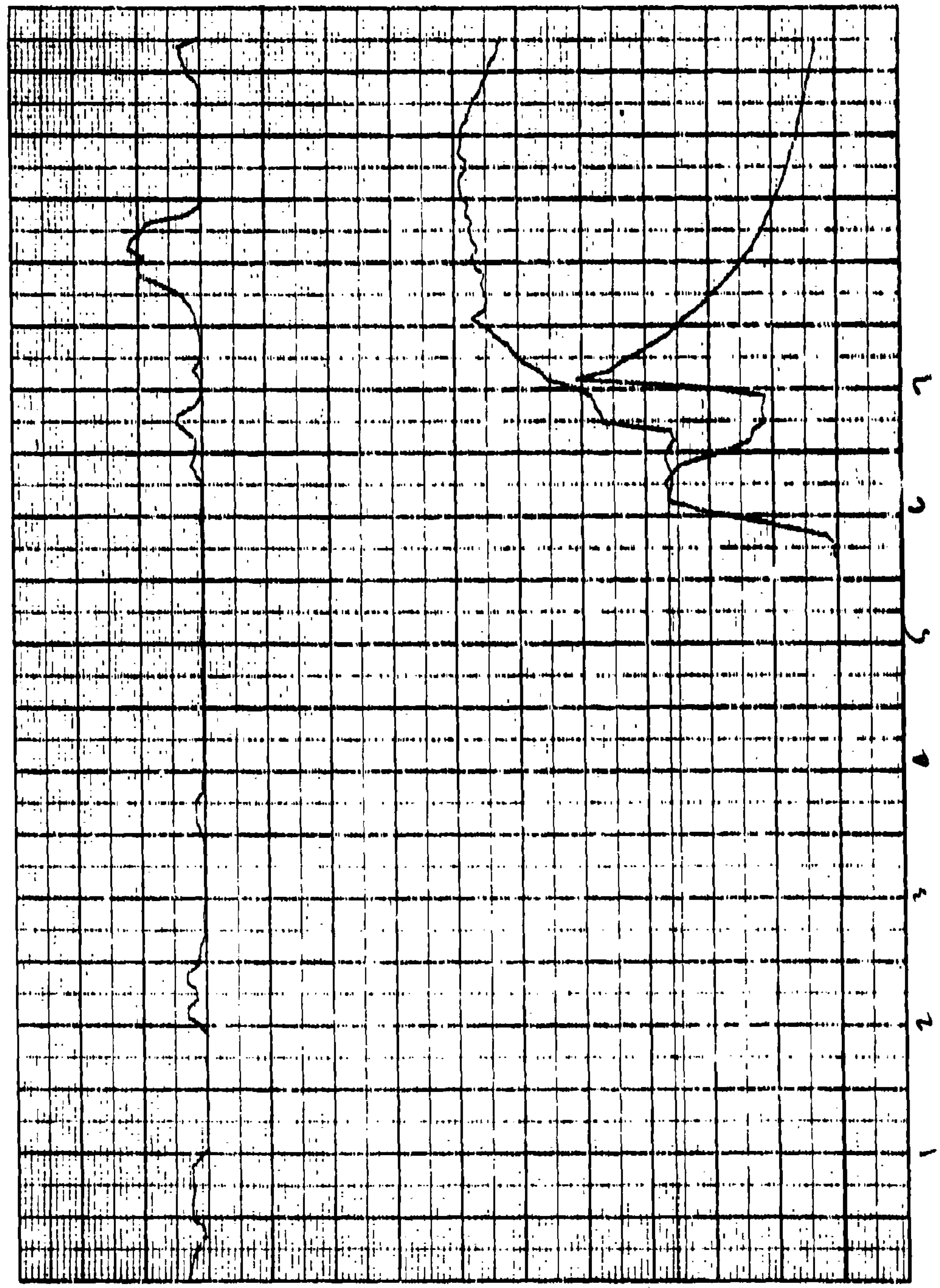

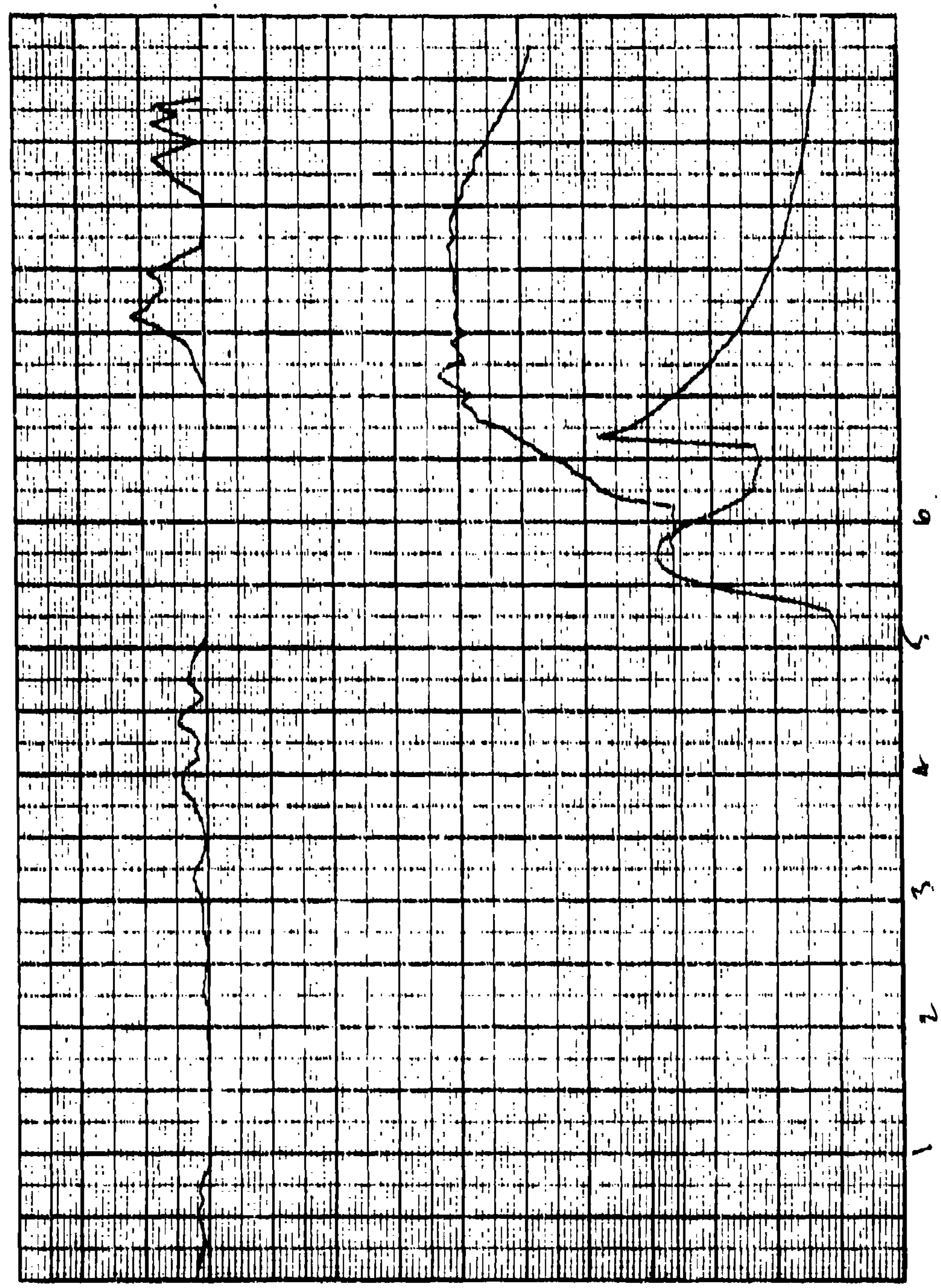
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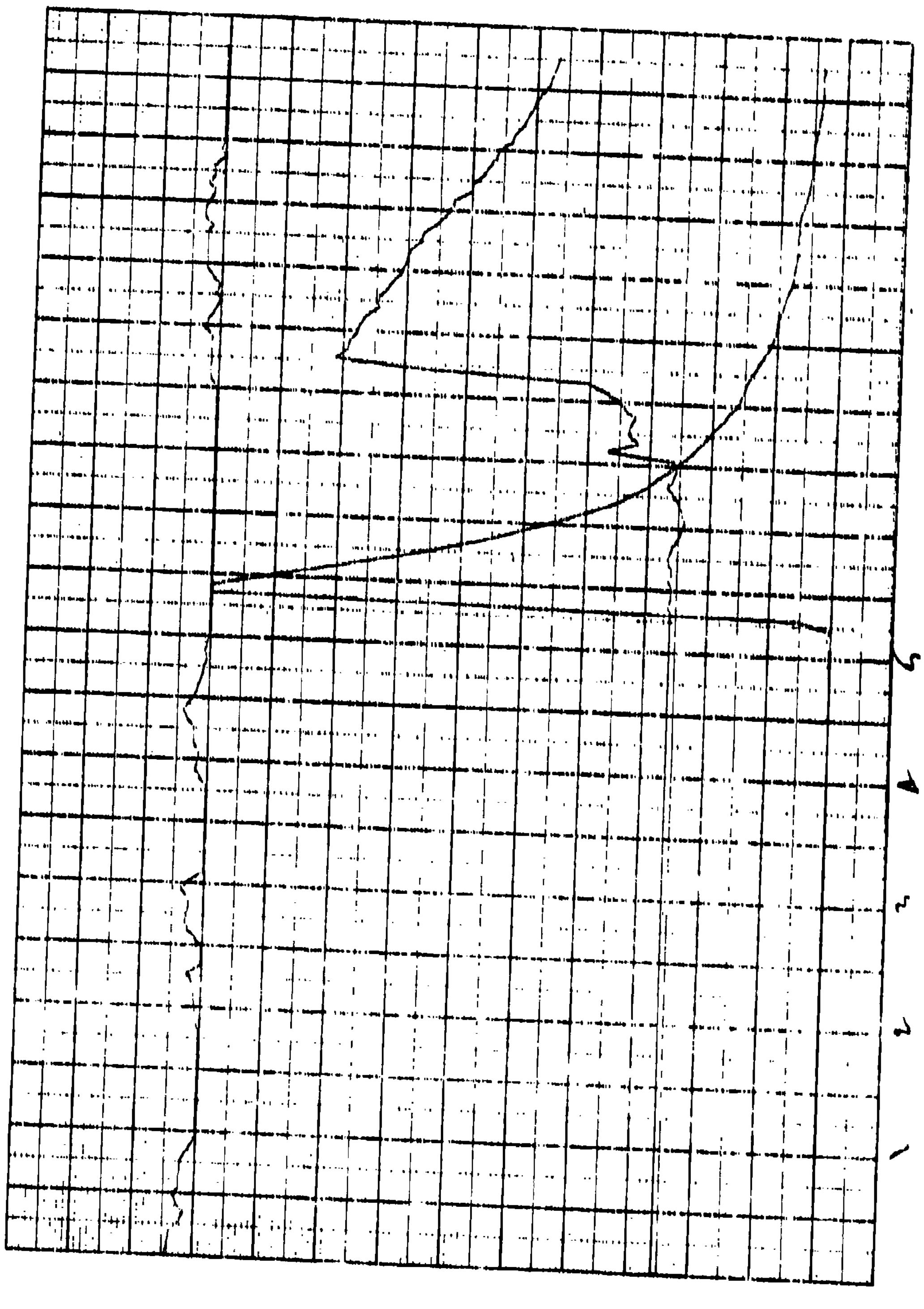


```
RUNNH

OPTION FOR P2   1=RR    2=P2MAX?2
DISTANCE TO FIRST LIGHT SCREEN?23
DISTANCE BETWEEN LIGHT SCREENS?22
K-RAD   1=YES  2=NO?2

P1 MAX     P2 MAX    P3 MAX    VELOCITY    TIME    B.E.  P.E.
-------------------------------------------------------------
ROUND NO--?1
   55.6      -.5        3.8          5845    5.46    .841  .569
   54.74      0         7.63
LS1 TO LS2 1658
P0 TO LS2 2513
ROUND NO--?9999

STOP AT LINE 2000

READY

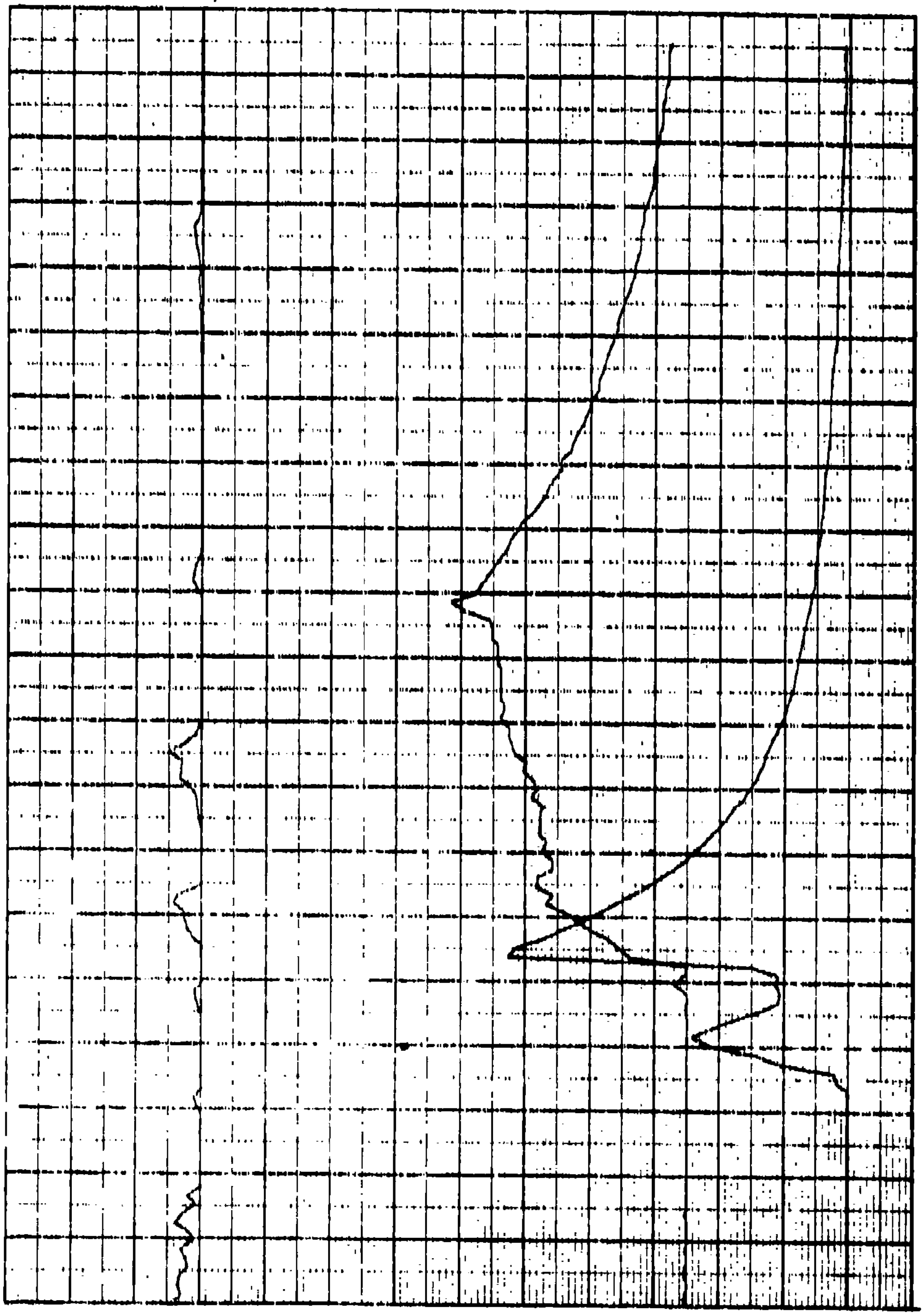
RUNNH

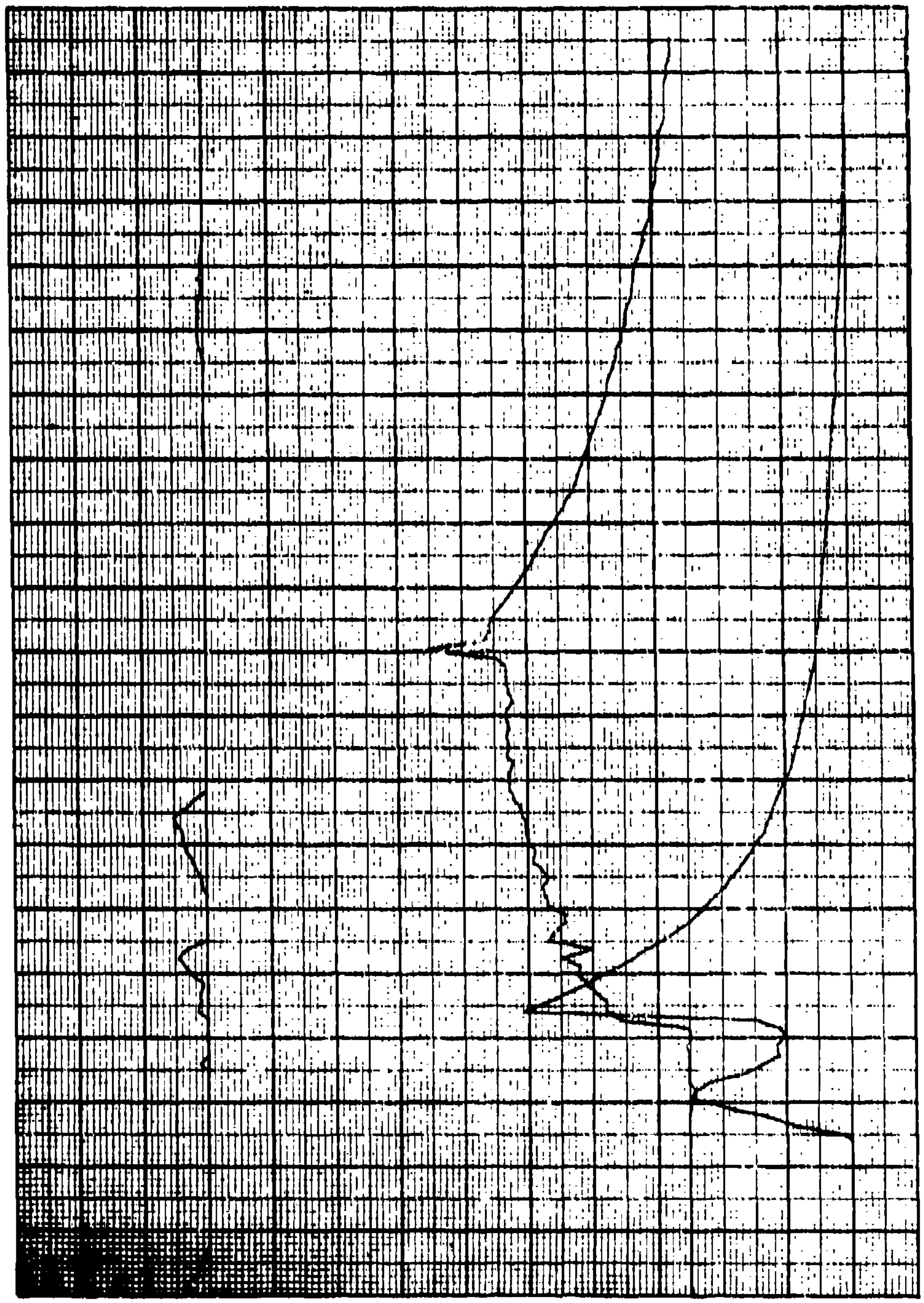
OPTION FOR P2   1=RR    2=P2MAX?2
DISTANCE TO FIRST LIGHT SCREEN?37.583
DISTANCE BETWEEN LIGHT SCREENS?7.833
K-RAD   1=YES  2=NO?2

P1 MAX     P2 MAX    P3 MAX    VELOCITY    TIME    B.E.  P.E.
-------------------------------------------------------------
ROUND NO--?2F
   48.6      -.9        4.16         2435    5.55    9.88888E-03
 .138
   52.69      0         7.66
LS1 TO LS2 2418
P0 TO LS2 2432
ROUND NO--?9999

STOP AT LINE 2000

READY
```





25MM PLASTIC CASE
AMMUNITION DEVELOPMENT

S/N: 16
DATE: 26 AUG 74
ENGR: GRAY
AMMO: CATTON-BURKETT

OBJECTIVE: To Observe The Effect Of Deterred Aft Charge And Different Forward Charges On Ballistic Performance

Test Fixture: IITRI, UNIVERSAL, RIA.
Cartridge Case: Dwg. No. SK 300460, Rev.____, Mat'l Nylon 12 - 35% Glass
Dwg. No. ________, Rev.____, Mat'l ________.
Projectile: Dwg. No. 300347, Rev. A, Plastic Band, 3000 Grain.
Primer: Type Pistol, Lot No.________, No.________.
Flash Tube: 4256W, 38 Special, ________.
Projectile Retention: 40 Mil NC, 10 Mil Mylar, I3150 To Fwd Grain Gray
Ignitor: Black Powder Class 3, Seals: Nylon - [illegible]
Propellant: Fwd Charge See Margin, Lot No.________.
Aft Charge 5472-1, Lot No.________.
Fwd Grain Overlight Insert N/A, Lot No.________.
Rucono 20 4.5 gms
~3" 1.010" ID
REMARKS: One & ½ Coats Neoprene
Rd. Length 6.075/6.085 (0.020 0.030" Crush up)

Fwd Charge	Round No.	Propellant Wt (Grams) FWD	AFT	Insert	Total Prop. Wt (Grams)	Ignitor Wt BP (Grams) (3)
5472-1	109	90.3	45.9	—	136.2	0.75
	110	90.6	45.8	—	136.4	0.75
	111	90.8	45.9	—	136.7	0.75
5473	112	88.2	45.5	—	133.7	0.75
	113	88.7	45.8	—	134.5	0.75
	114	85.5	45.1	—	131.2	0.75
5463	115	88.8	45.8	—	134.6	0.70
	116	89.2	45.9	—	135.1	0.70
	117	89.5	45.7	—	135.2	0.70
5469	118	90.5	45.3	—	135.8	0.75
	119	90.6	45.4	—	136.0	0.80
	120	90.5	45.1	—	135.2	0.80

FORM NO. SG-555-81

1½ coats Neoprene on aft grain
pistol primer
S/N 18
BP③

RUNNH

```
OPTION FOR P2   1=RR    2=P2MAX?2
DISTANCE TO FIRST LIGHT SCREEN?37.583
DISTANCE BETWEEN LIGHT SCREENS?7.833
K-RAD   1=YES  2=NO?2

P1 MAX     P2 MAX    P3 MAX    VELOCITY    TIME    B.E.  P.E.
--------------------------------------------------------------
ROUND NO--?109                                                      Pwd Chg
   60.3       -.8       9.12        3728       8.76     .022  .261
   84.74      0         0                                           E472-1
LS1 TO LS2 3659
P3 TO LS2 3715
ROUND NO--?110                                                      0.75 gm
   64.8       -.5       8.61        3728       6.56     .022  .243
   92.1       0         0
LS1 TO LS2 3659
P3 TO LS2 3715
ROUND NO--?111
   24.8       -.3       2.56        1827       10.2     5.00000E-03
 .153
   57.06      0         5.59
LS1 TO LS2 1834
P3 TO LS2 1828


ROUND NO--?112
   64.4       -.2       5.64        3276       6.42     .017  .189
   76.73      0         1.43                                        5473
LS1 TO LS2 3243
P3 TO LS2 3270                                                      0.75 gm
ROUND NO--?113
   55.2       -.1       5.69        2922       6.35     .014  .175
   79.53      0         3.86
LS1 TO LS2 2912
P3 TO LS2 2920
ROUND NO--?114
   87.9       .2        8.68        3974       6.42     .025  .283
   100.71     1.12      .01
LS1 TO LS2 4049
P3 TO LS2 3987
```

```
ROUND NO--?115
   34.8       .2          3.06        2129     9.17     7.00000E-03
 .147                                                                     5463
   61.65      .52         7.85
LS1 TO LS2 2105                                                           0.70 gm
P3 TO LS2 2125
ROUND NO--?116
   29.2       .1          2.73        1911     9.51     6.00000E-03
 .142
   63.06      .78         8.89
LS1 TO LS2 1927
P3 TO LS2 1914
ROUND NO--?117
   72.7       .1          8.6         3677     8.96     .022  .211
   96.03      .86         1.15
LS1 TO LS2 3659
P3 TO LS2 . 74
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ROUND NO--?118
   73.8       .2                                                          8446-9
   118.08     3.62        10.46       3833     22.63    .023  .225
                          0                                               0.75 gm
LS1 TO LS2 3781
P3 TO LS2 3824
ROUND NO--?119
   61.5       .2          10.81       3702     9.03     .022  .252        0.80
   108.77     1.85        .01
LS1 TO LS2 3659
P3 TO LS2 3695
ROUND NO--?120
   32.6       .2          3.48        1988     11.16    6.00000E-03       0.80
 .137
   71.97      2.39        10.5
LS1 TO LS2 1995
P3 TO LS2 1989
ROUND NO--?9999

STOP AT LINE 2000

READY
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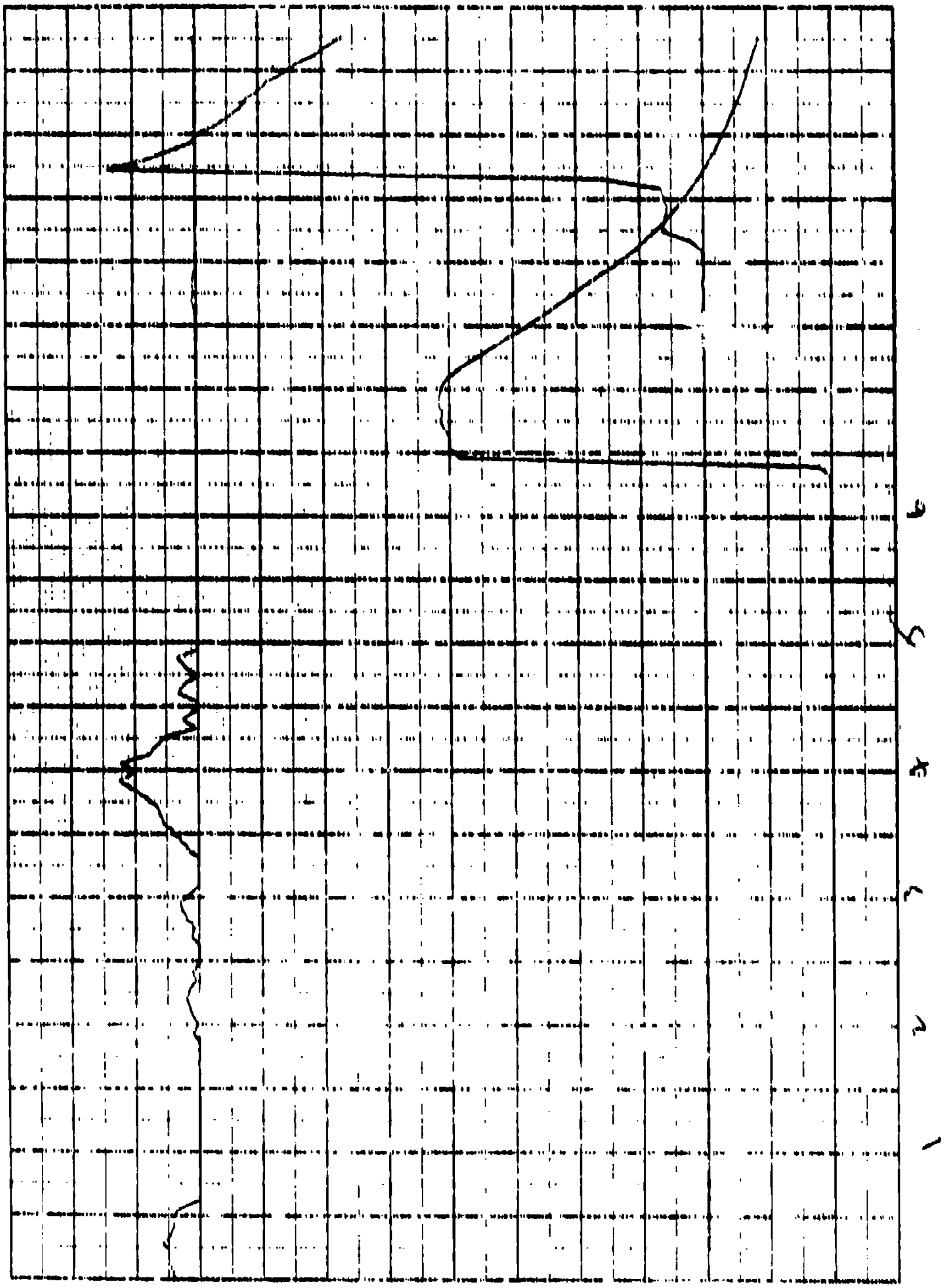

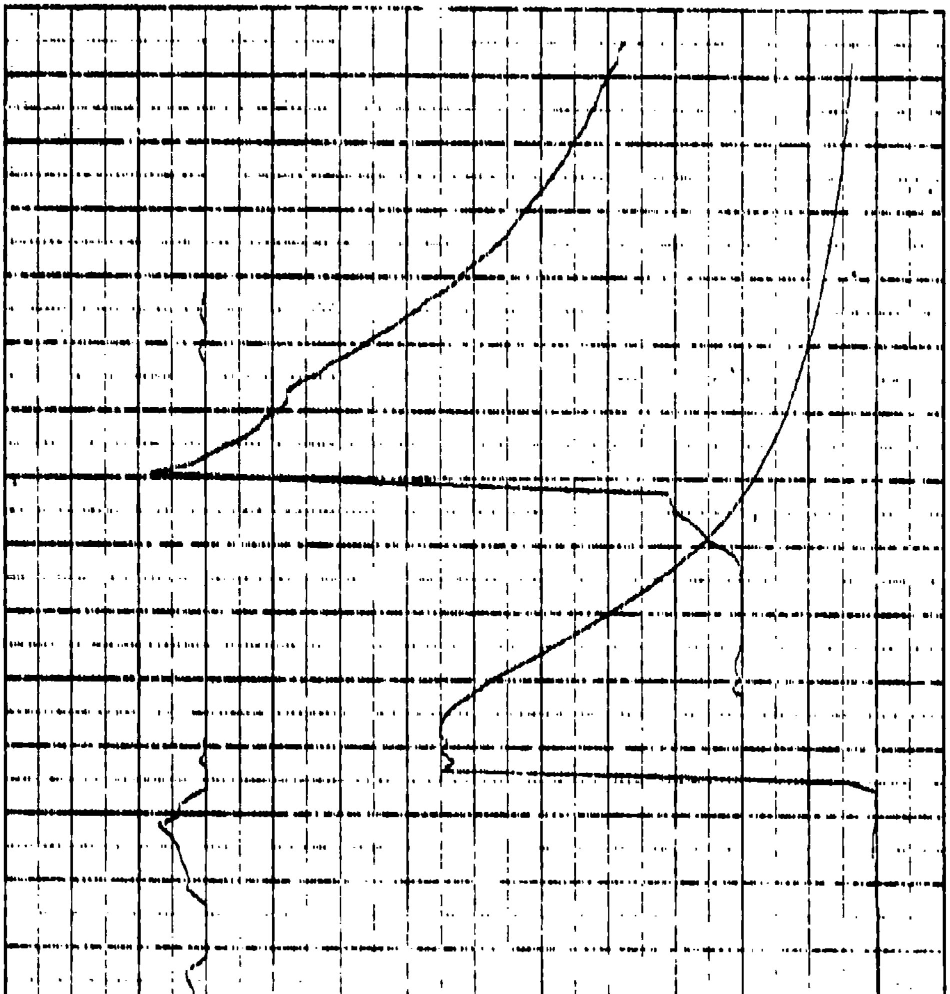

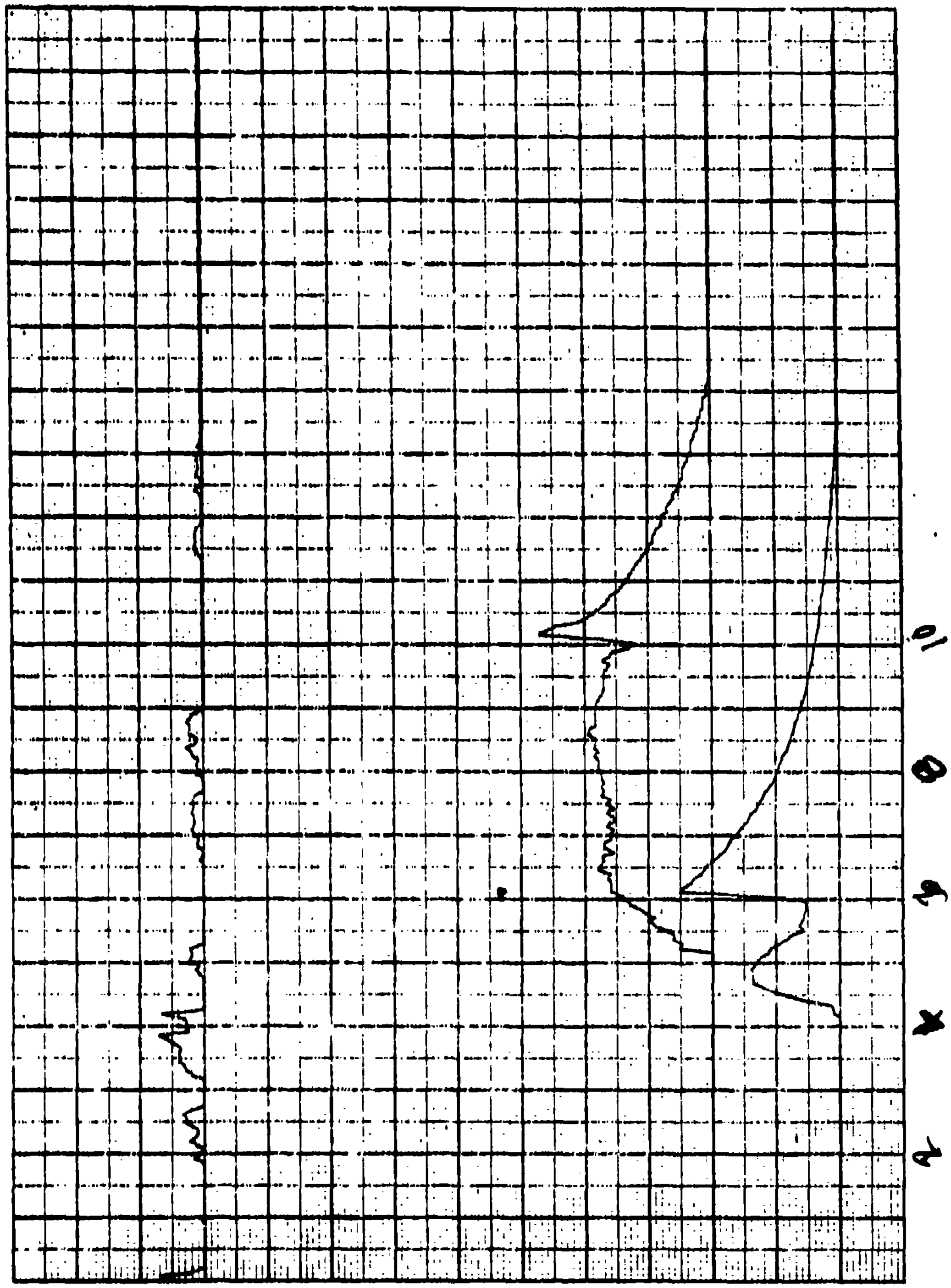

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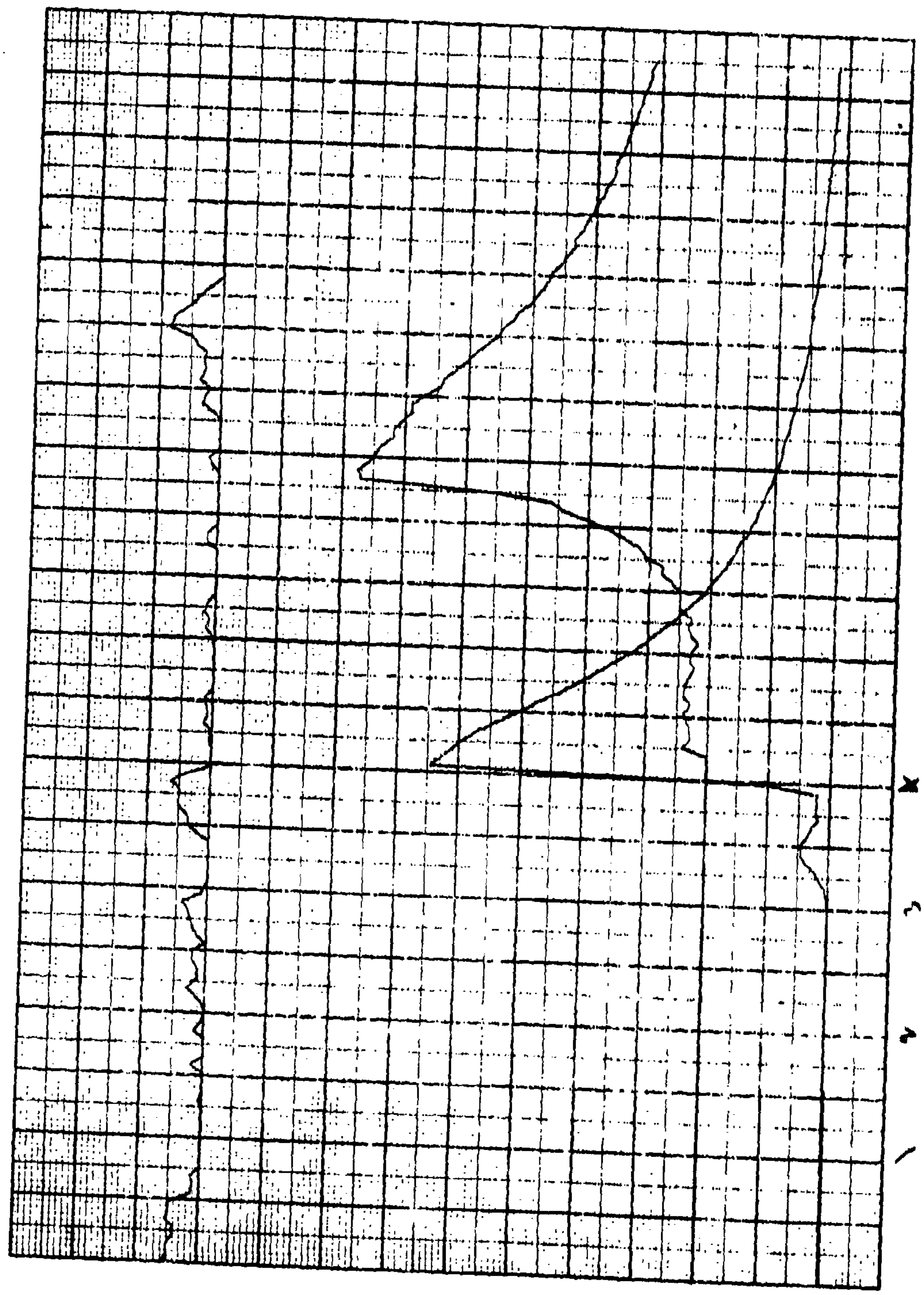

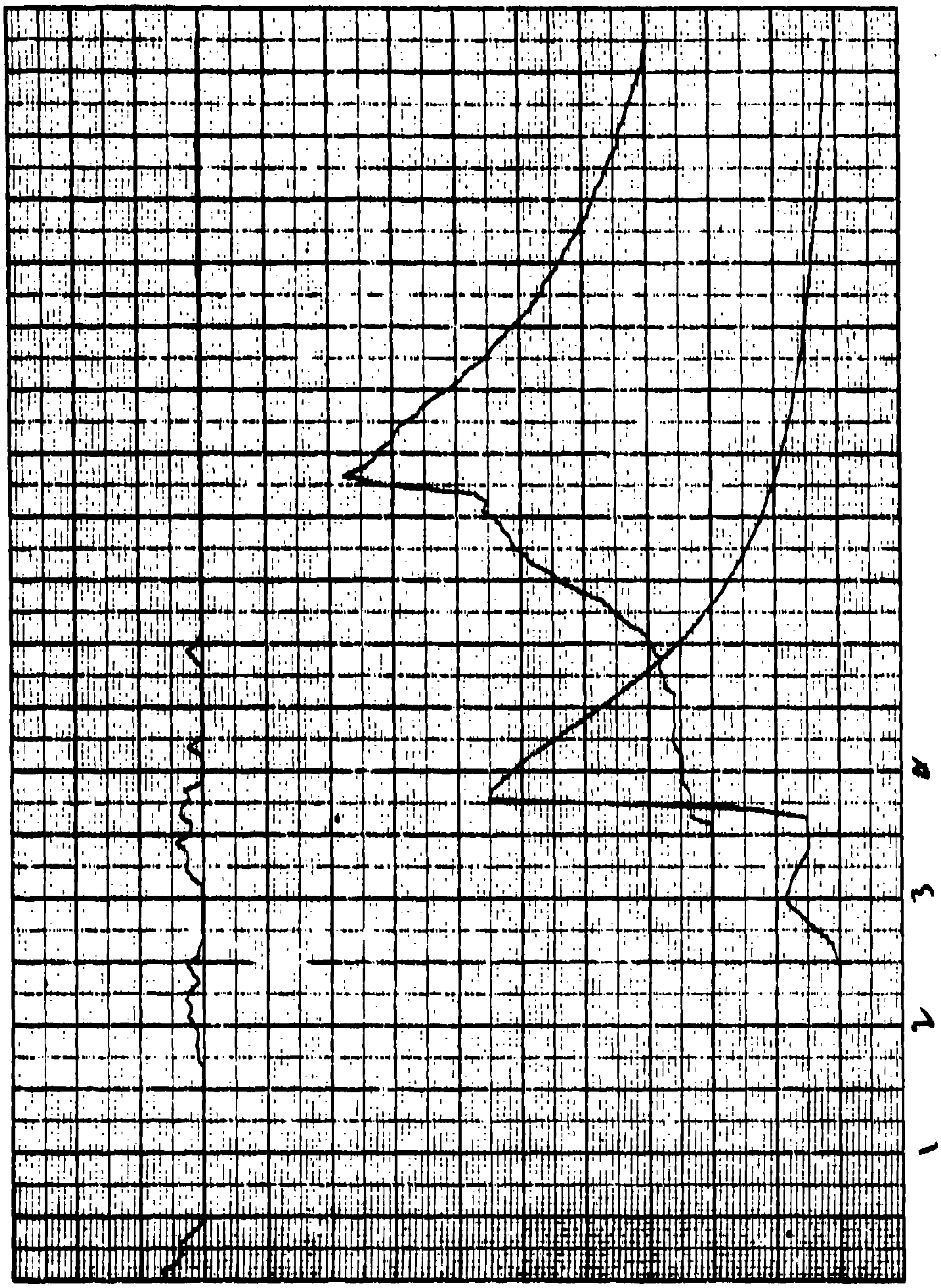
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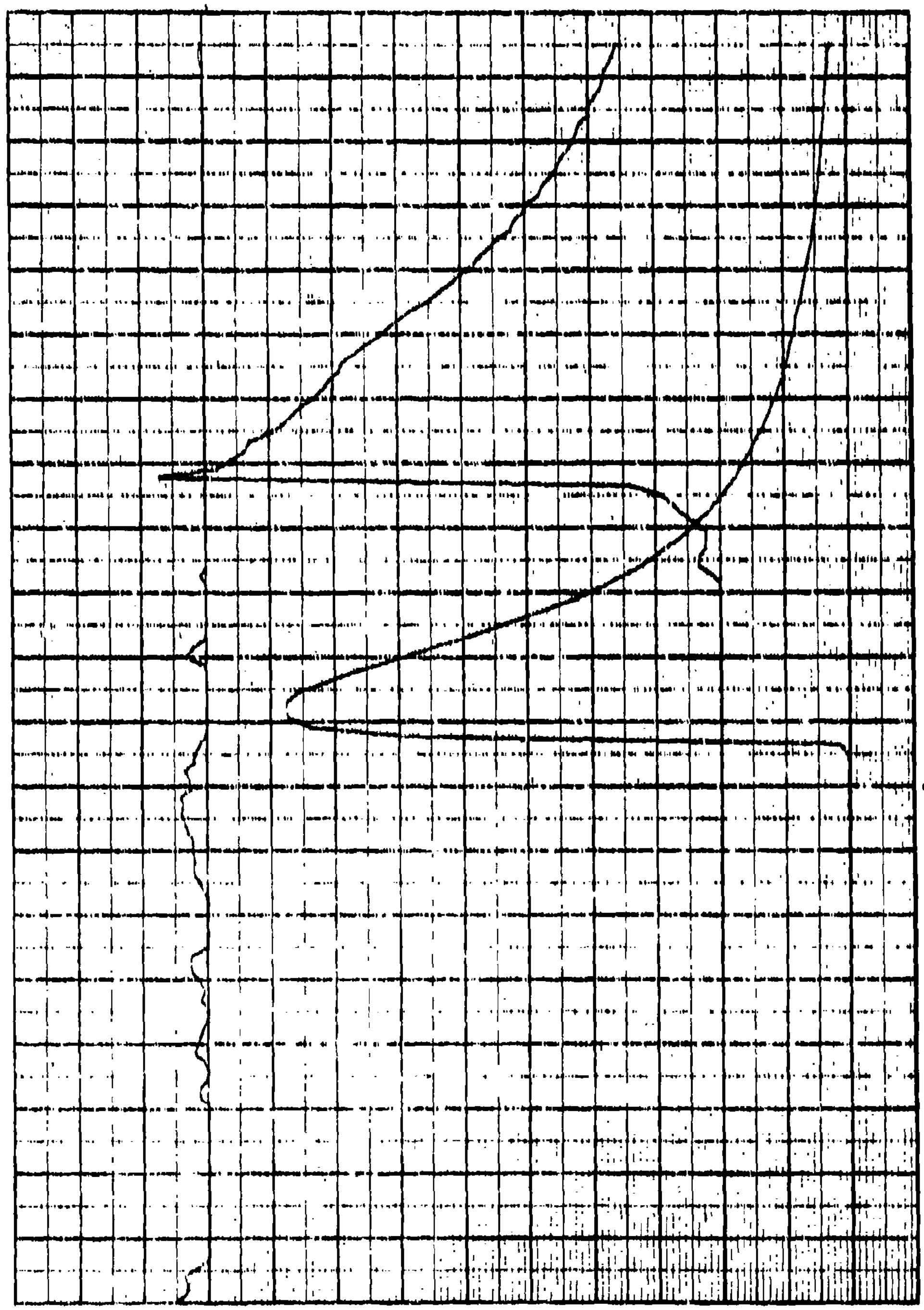

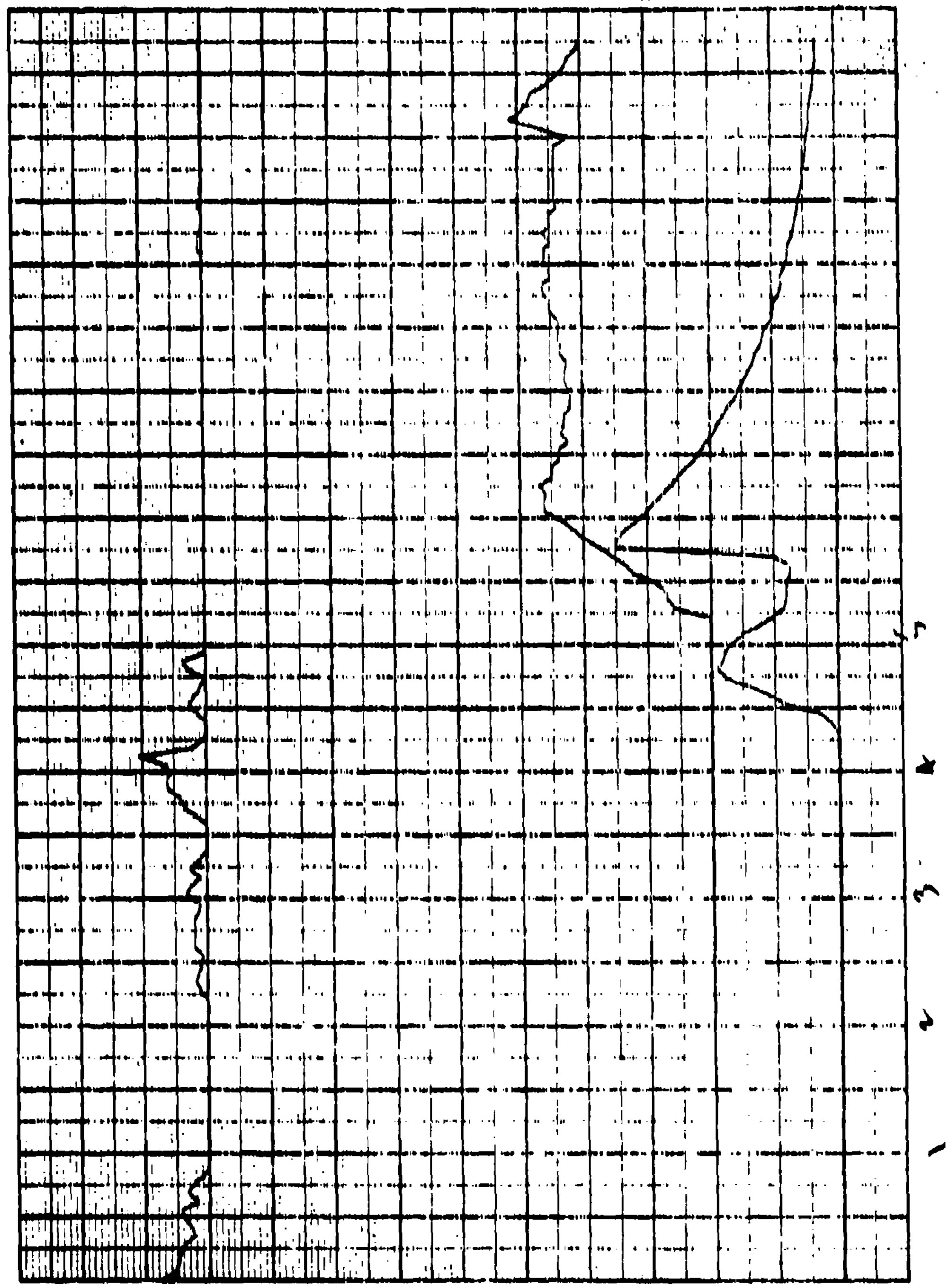

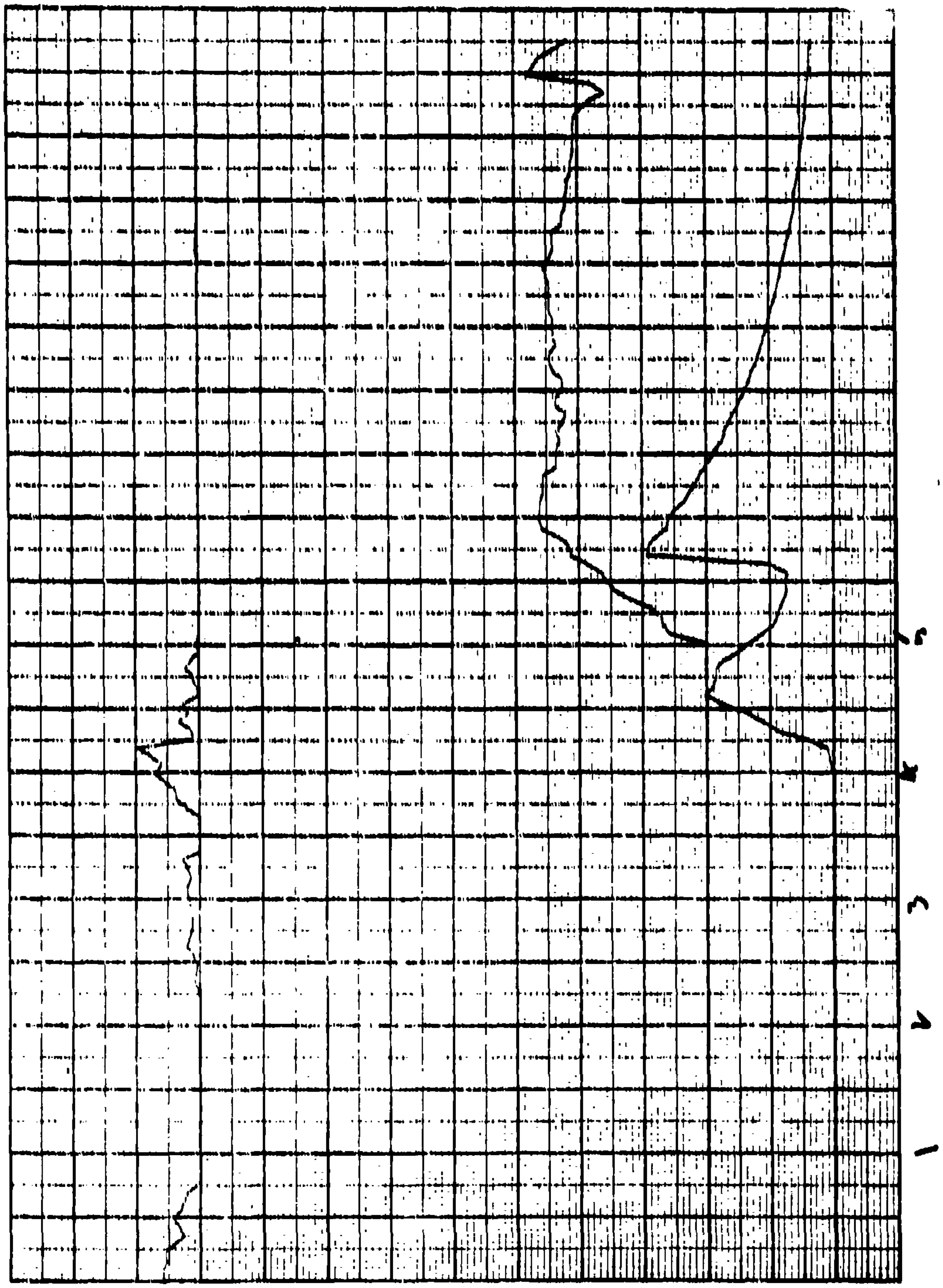

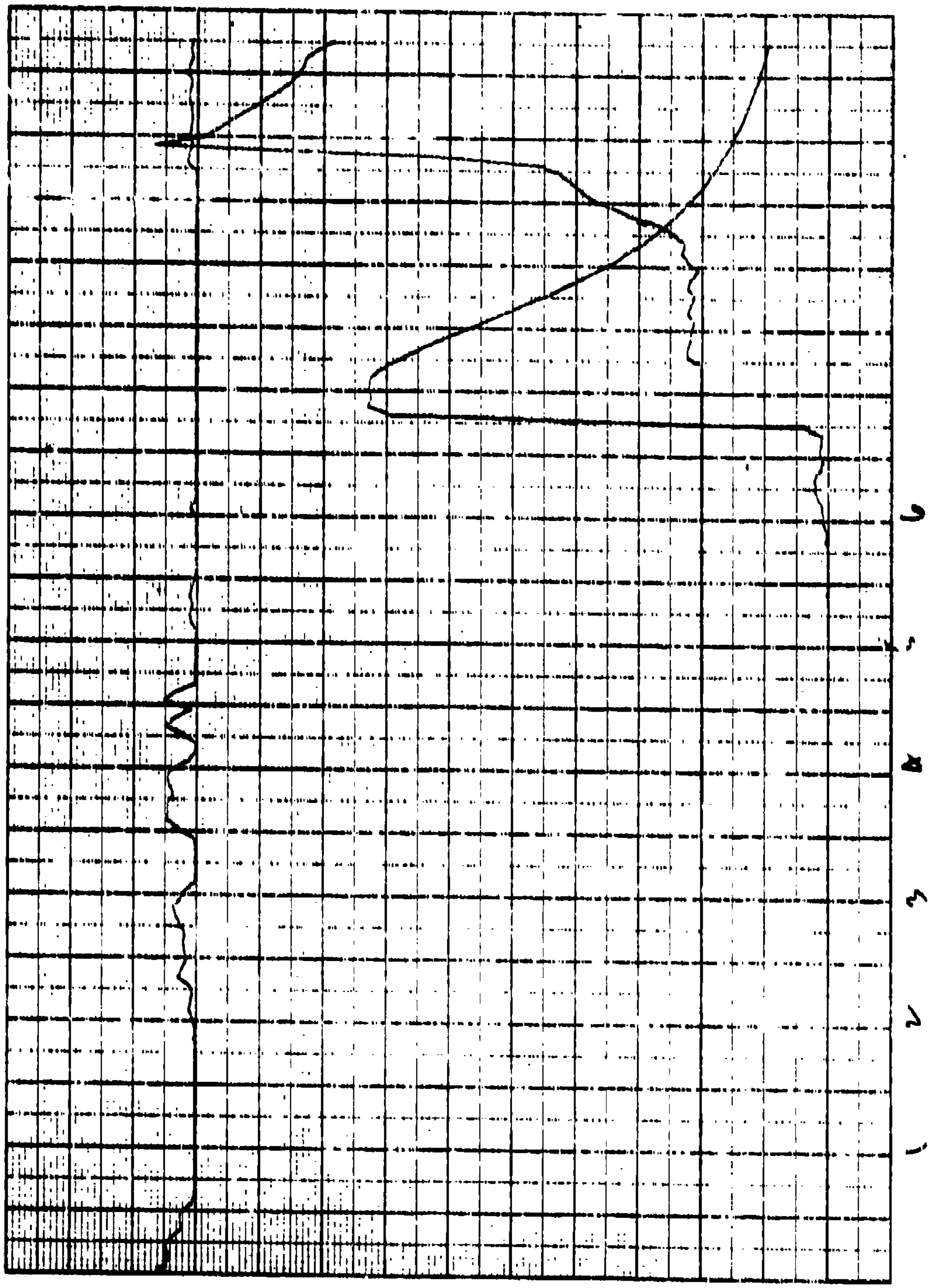

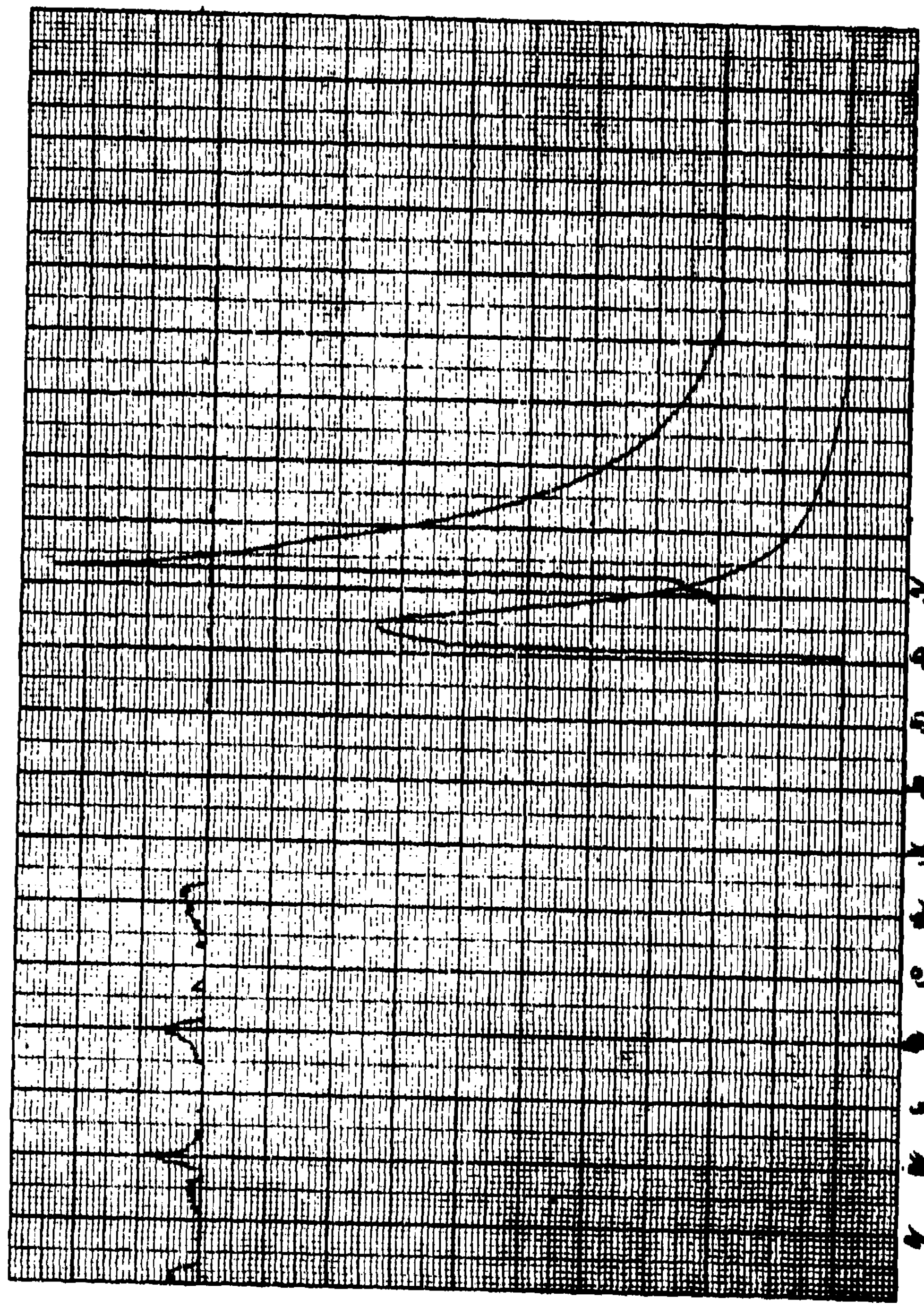

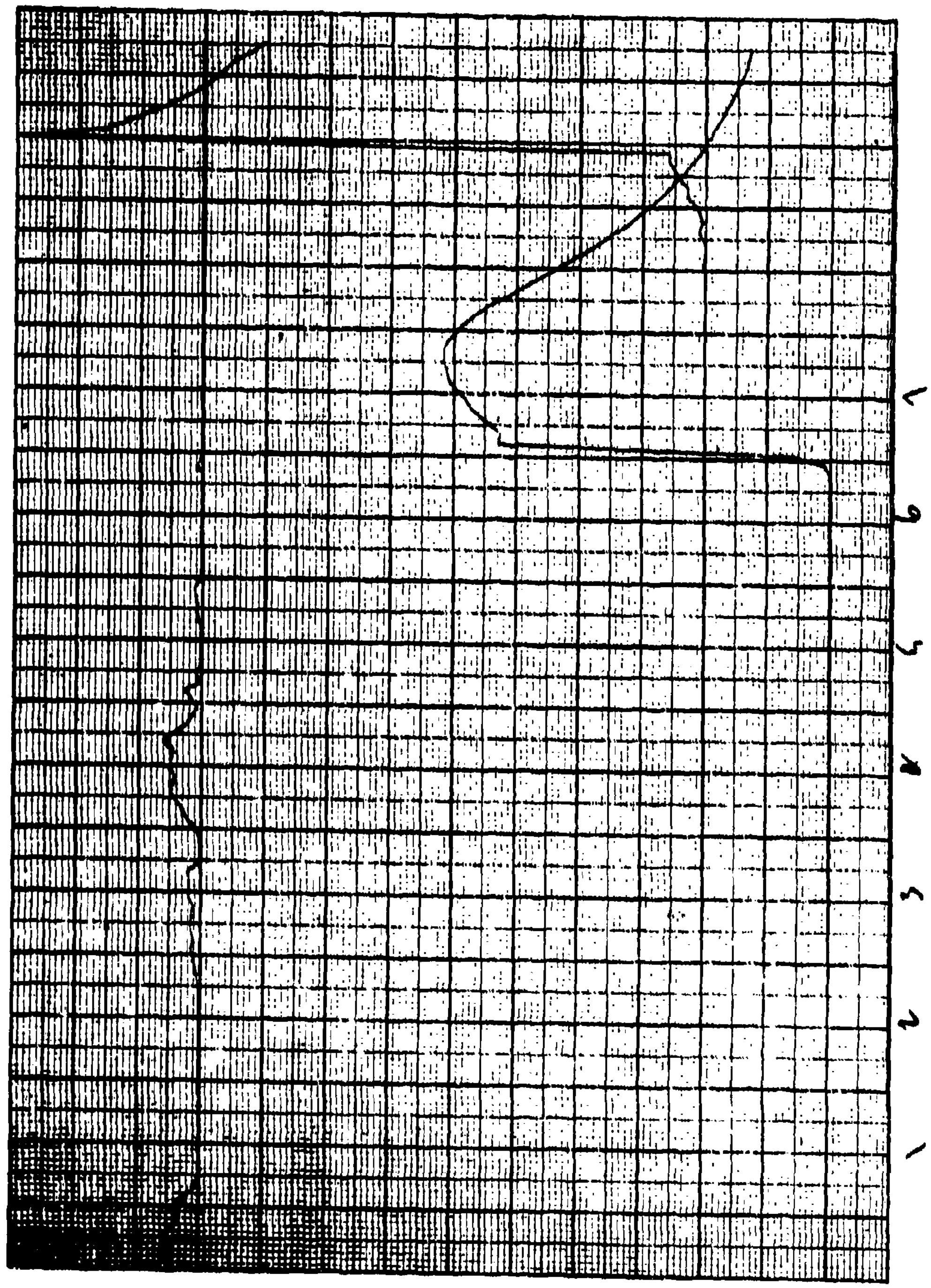
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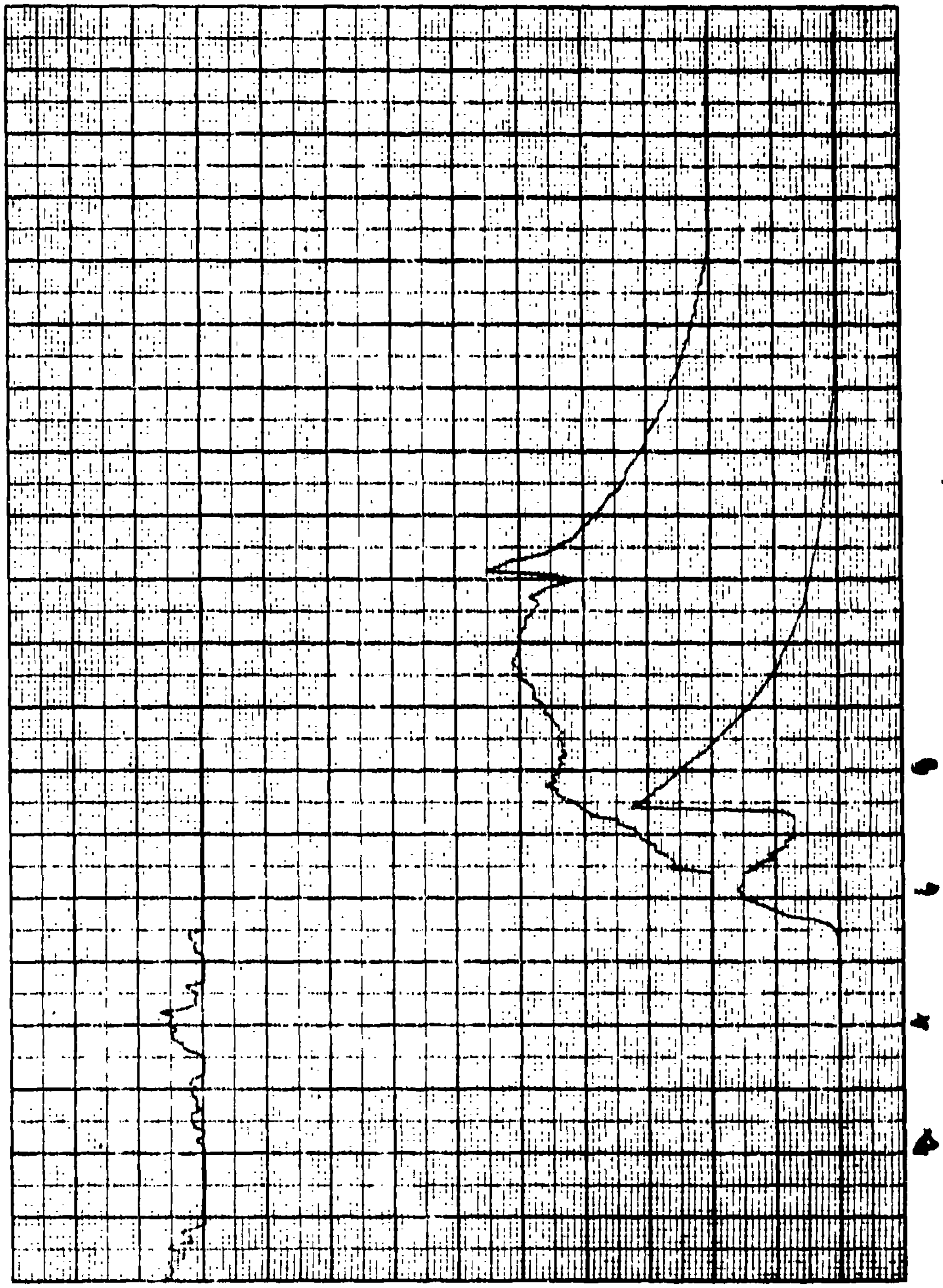

25MM PLASTIC CASE
AMMUNITION DEVELOPMENT

S/N: 17
DATE: 29 AUG 74
ENGR: CABY
AMMO: CATRON - BURKETT

OBJECTIVE: TO OBSERVE THE EFFECT OF DETERRED 5479 AFT CHARGES AND DIFFERENT FWD CHARGES ON BALLISTIC PERFORMANCE

Test Fixture: IITRI, UNIVERSAL, RIA.
Cartridge Case: Dwg. No. SK 300460, Rev. ____, Mat'l NYLON 12, 38% GLASS
Dwg. No. ________, Rev. ____, Mat'l ________.
Projectile: Dwg. No. 300347, Rev. A, Plastic Band, 3000 Grain.
Primer: Type SM/HSR, Lot No. ________, No. CCI 450M - Rd. No. 127 - 132
Flash Tube: 3256W, 38 Special, ________.
Projectile Retention: 40 Mil NC, 10 Mil Mylar, 33/35 BAND FWD GRAIN ONLY
Ignitor: BLACK POWDER CLASS 3, Seals: NYLON
Propellant: Fwd Charge [illegible] MARGIN, Lot No. ________.
Aft Charge 5479, Lot No. E-22.
Insert N/A, Lot No. ________.

FWD ½ OVERLAP

MICARBOL +12.5% NYLON 12

~3/8" 1.010" OD

REMARKS: 2½ COATS NEOPRENE DETERRENT
RD LENGTH 6.075/6.085 (0.020/0.030 IN CRUSH UP)

FWD CHARGE	ROUND NO.	PROPELLANT WT (GRAMS) FWD	AFT	INSERT	TOTAL PROP. WT (GRAMS)	IGNITOR WT BP (GRAMS) (3)
5472-1	121	90.3	46.0	—	136.3	0.75
	122	90.1	46.1	—	136.2	0.75
	123	90.1	46.0	—	136.1	0.75
5013	Ⓑ 124	90.4	45.6	—	136.0	0.75
	125	90.2	45.6	—	136.8	0.75
	126	90.1	45.9	—	136.0	0.75
5013	Ⓑ 127 Ⓐ	90.6	45.9	—	136.5	0.75
	128 Ⓐ	90.7	45.7	—	136.4	0.75
	Ⓑ 129 Ⓐ	90.2	45.8	—	136.0	0.75
6446-9	130 Ⓐ	90.8	46.0	—	136.8	0.75
	131 Ⓐ	90.3	46.0	—	136.3	0.75
	132 Ⓐ	90.3	45.9	—	136.2	0.75

Ⓐ 450M PRIMER (SMALL RIFLE MAGNUM)

1" x 1" WAD

FORM NO. SG-555-81

Ⓑ DIFF. NYLON SEAL MAT'L.

NOTE: 6479 aft grain

S/N 17

2½ COATS NEOPRENE ON AFT GRAIN
121 - 126 PISTOL PRIMER
127 - 132 SMALL RIFLE MAGNUM

```
RUNNH

OPTION FOR P2    1=RR     2=P2MAX?2
DISTANCE TO FIRST LIGHT SCREEN?37.583
DISTANCE BETWEEN LIGHT SCREENS?7.833
K-RAD    1=YES   2=NO?2

P1 MAX      P2 MAX     P3 MAX     VELOCITY     TIME      B.E.  P.E.       Fwd
----------------------------------------------------------------------
ROUND NO--?121
   57.1      -1.3        8.41        3603       26.27     .021  .257      8472-1
   44.61      0          0
LS1 TO LS2 3546
P3 TO LS2 3593
ROUND NO--?122
   60        -.4         8.57        3628       28.26     .021  .248
   99.69      0          0
LS1 TO LS2 3546
P3 TO LS2 3613
ROUND NO--?123
   60.5      -.3         7.8         3603       25.99     .021  .243
   108.03     0          0
LS1 TO LS2 3659
P3 TO LS2 3613



ROUND NO--?124
   72.6      -.2         9.09        3677       23.66     .022  .211      8475
   148.69     0          6.72
LS1 TO LS2 3781
P3 TO LS2 3695
ROUND NO--?125
   88.4      -.2         7.35        3916       22.63     .024  .196
   123.37     0          0
LS1 TO LS2 3918
P3 TO LS2 3915
ROUND NO--?126
   78.3      -.1         7.22        3677       6.9       .022  .195
   99.44      0          1.32
LS1 TO LS2 3659
P3 TO LS2 3674
```

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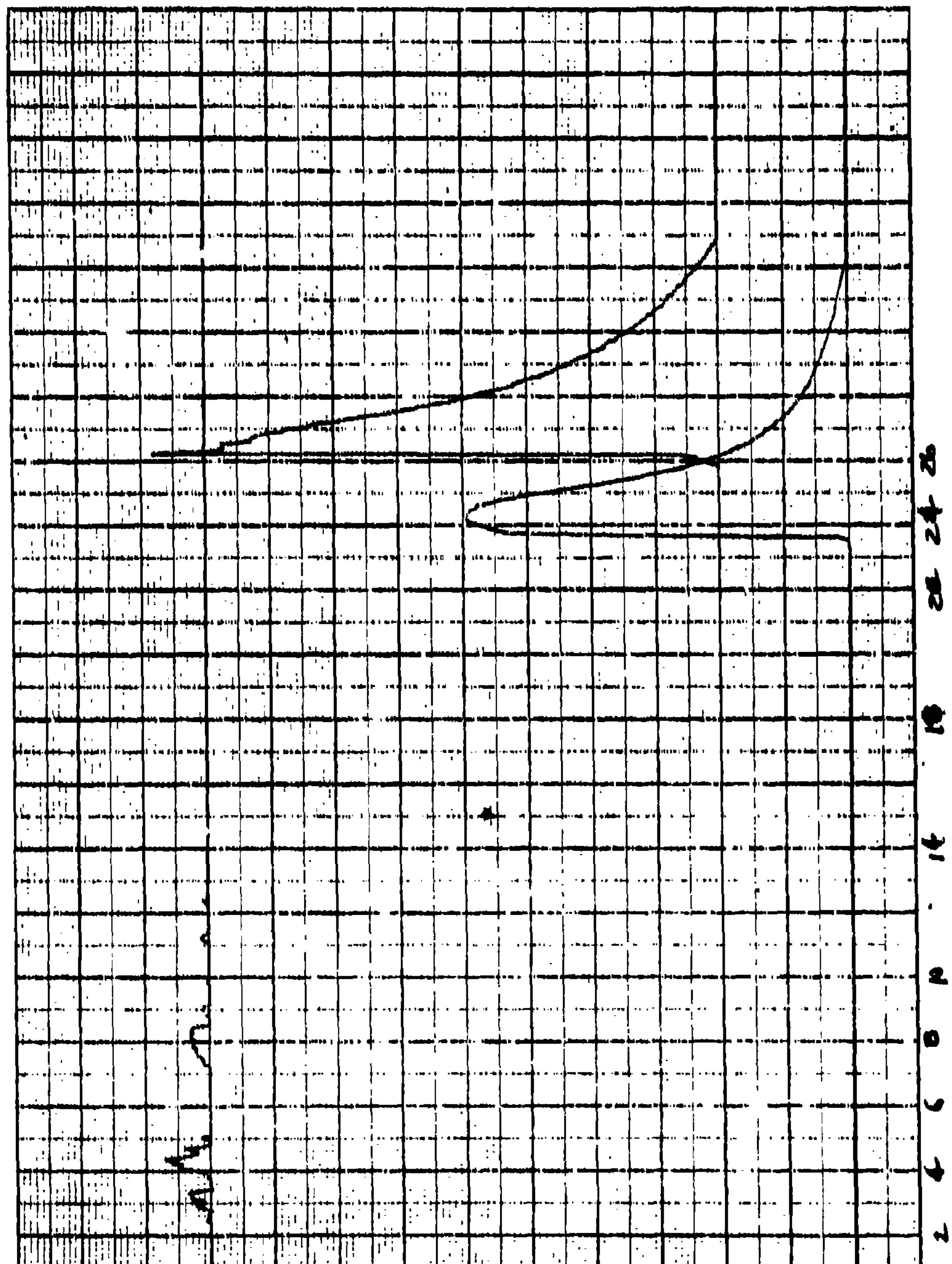
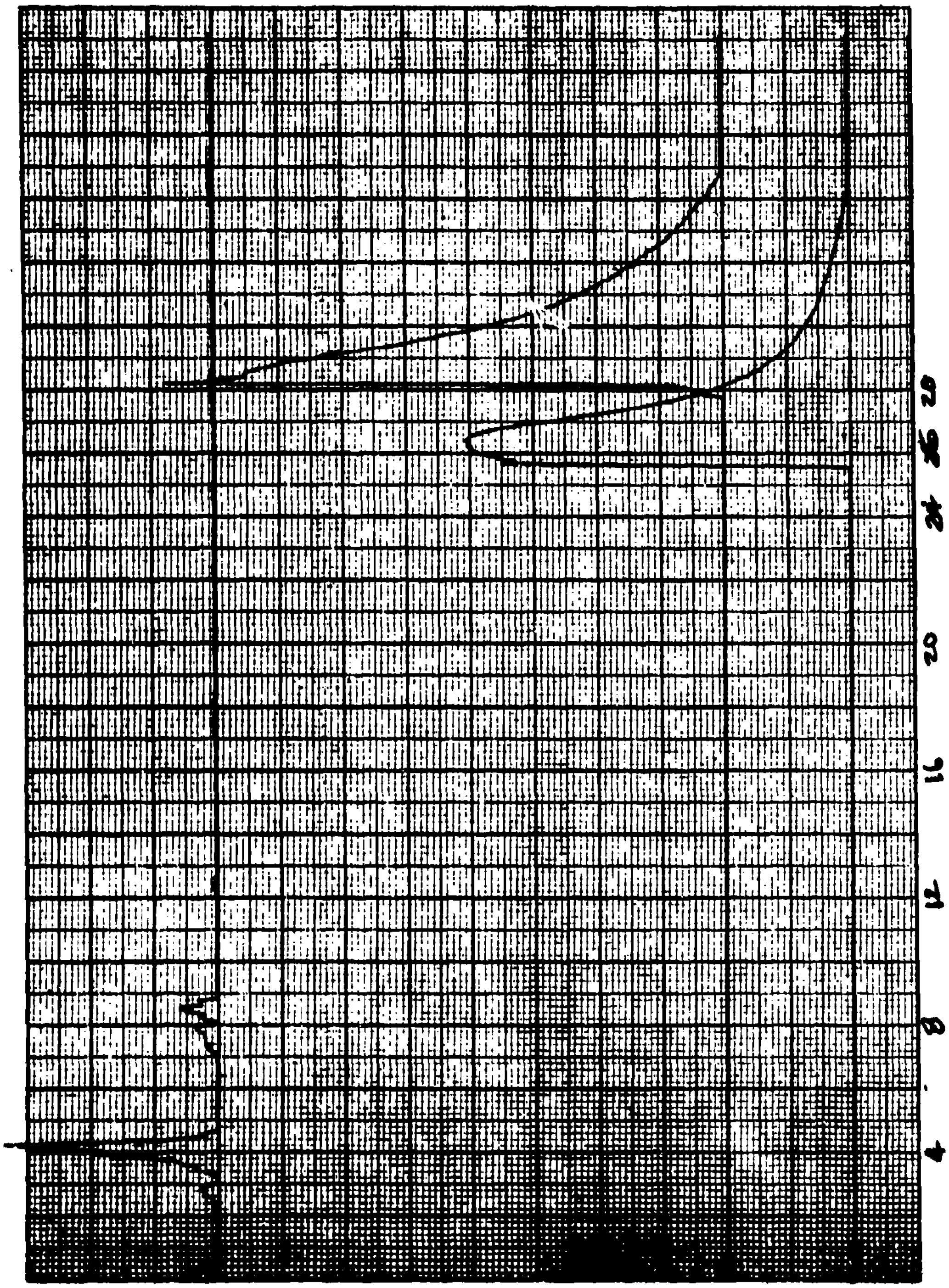
ROUND NO--7127
    53          -.1     6.96       3816    9.65    .02   .260      5463
    106.88       6      6
LS1 TO LS2 3846
PO TO LS2 3816
ROUND NO--7128
    27.4        -.1     9.18       2676    10.95   .011  .297
    86.48        6      .17
LS1 TO LS2 2642
PO TO LS2 2676
ROUND NO--7129
    76.7        -.1     7.63       3833    22.63   .020  .217
    117.01       6      6
LS1 TO LS2 3916
PO TO LS2 3846

ROUND NO--7130
    88.4        -.1     9.59       3677    24.41   .022  .224      8446-9
    129.59       6      6
LS1 TO LS2 3689
PO TO LS2 3674
ROUND NO--7131
    62.9        -.1     7.28       3387    7.73    .018  .280
    91.38        6      8.03
LS1 TO LS2 3409
PO TO LS2 3371
ROUND NO--7132
    67.2        -.1     7.38       3378    7.64    .018  .192
    91.4         6      8.11
LS1 TO LS2 3409
PO TO LS2 3389
```

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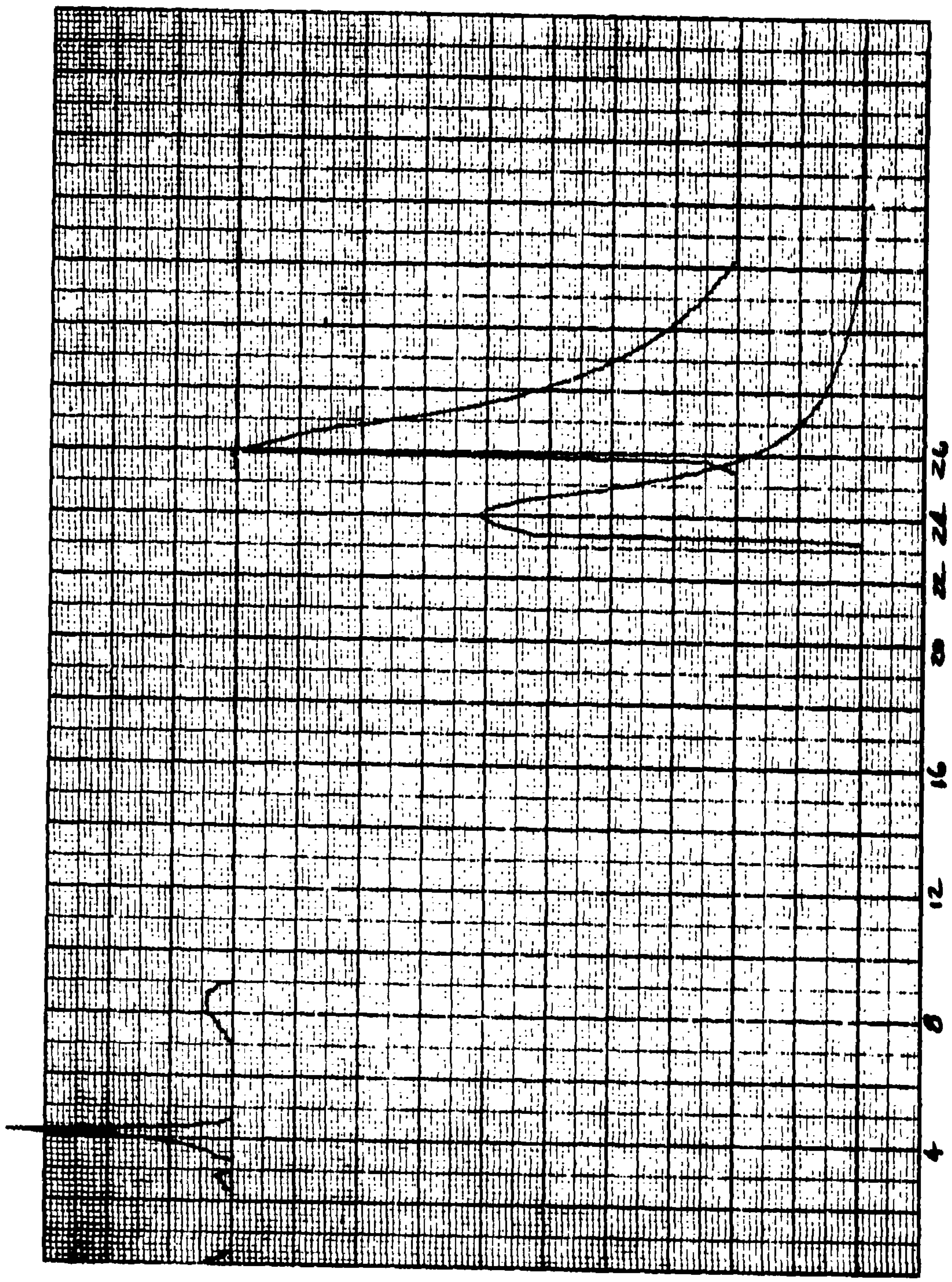
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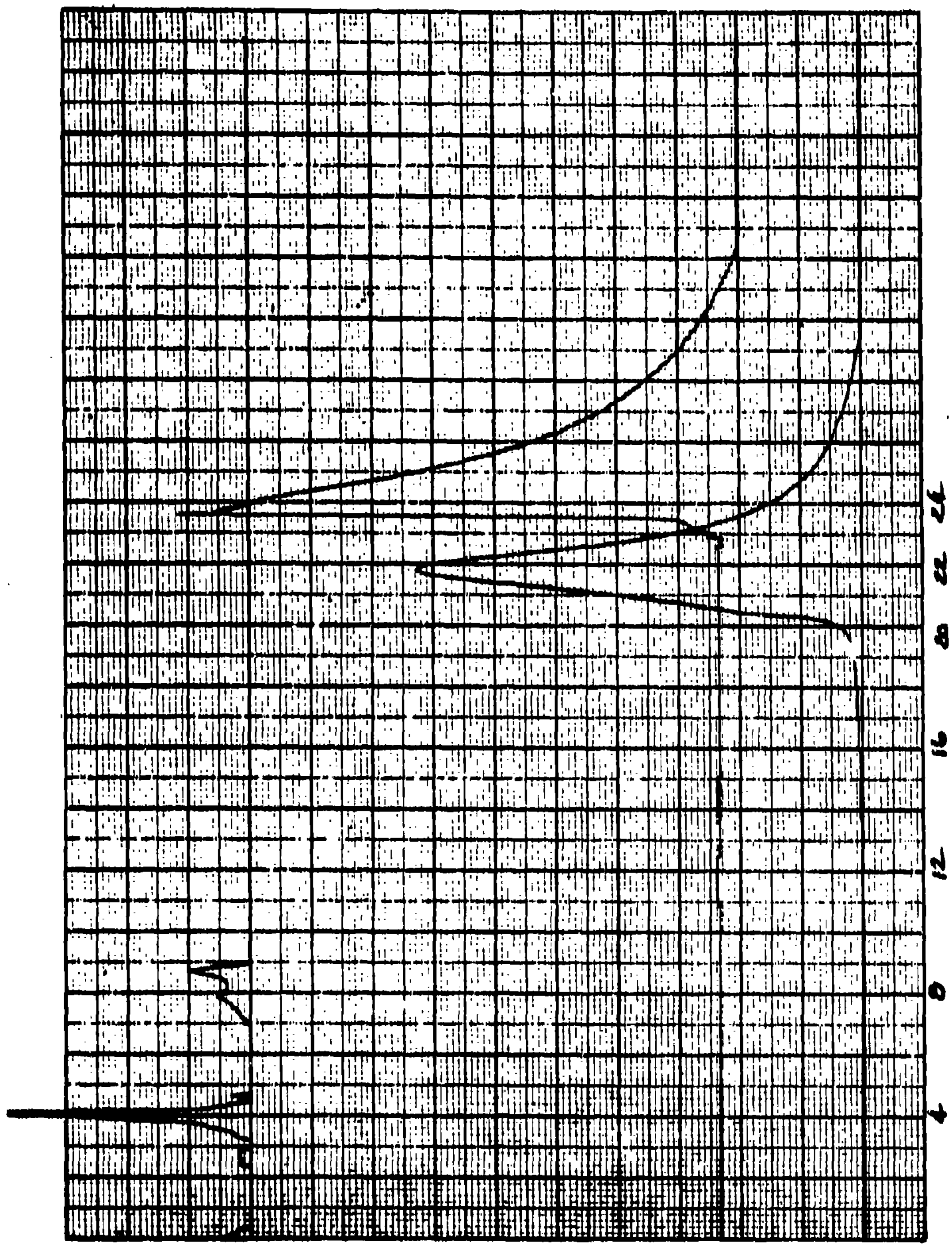
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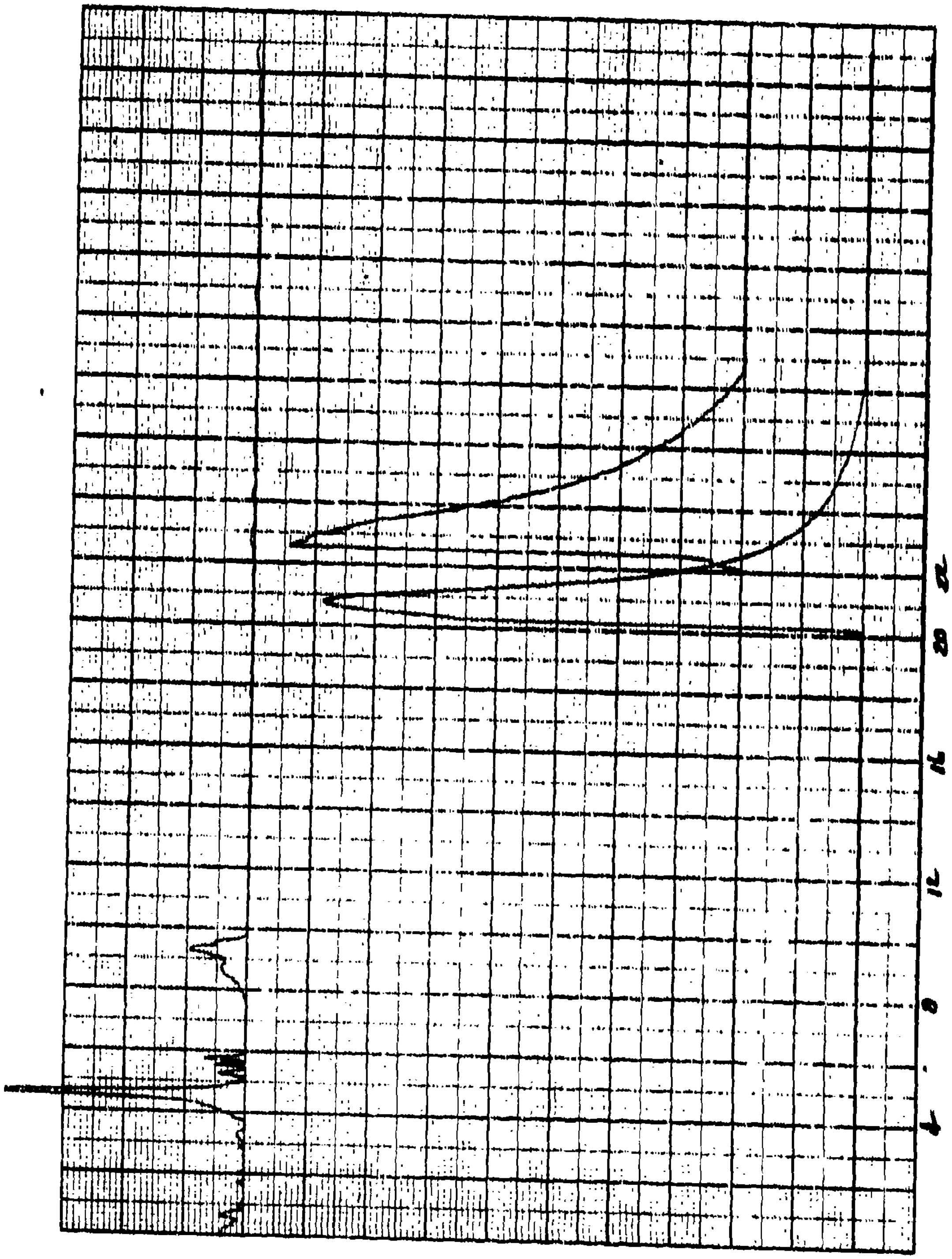
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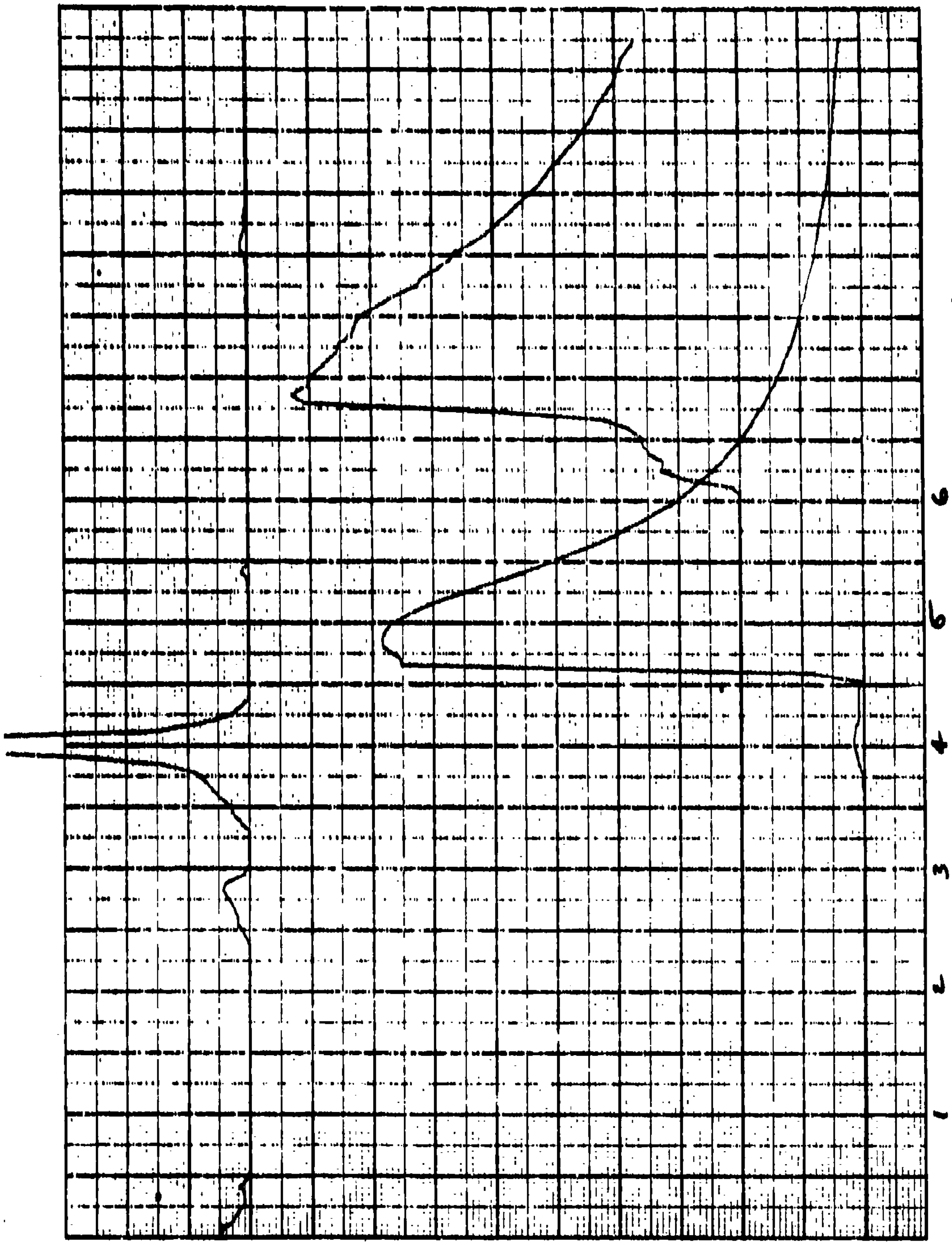

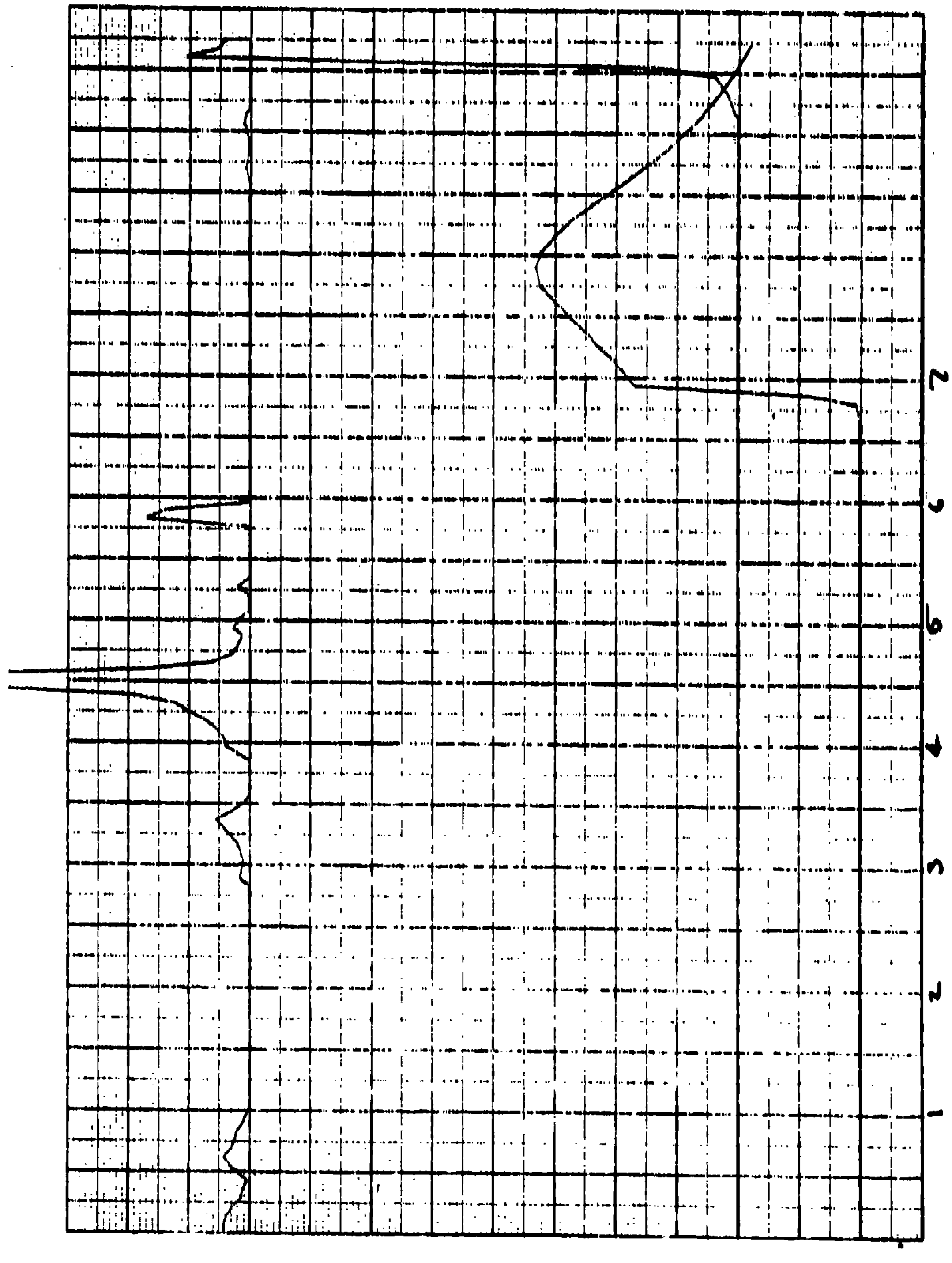
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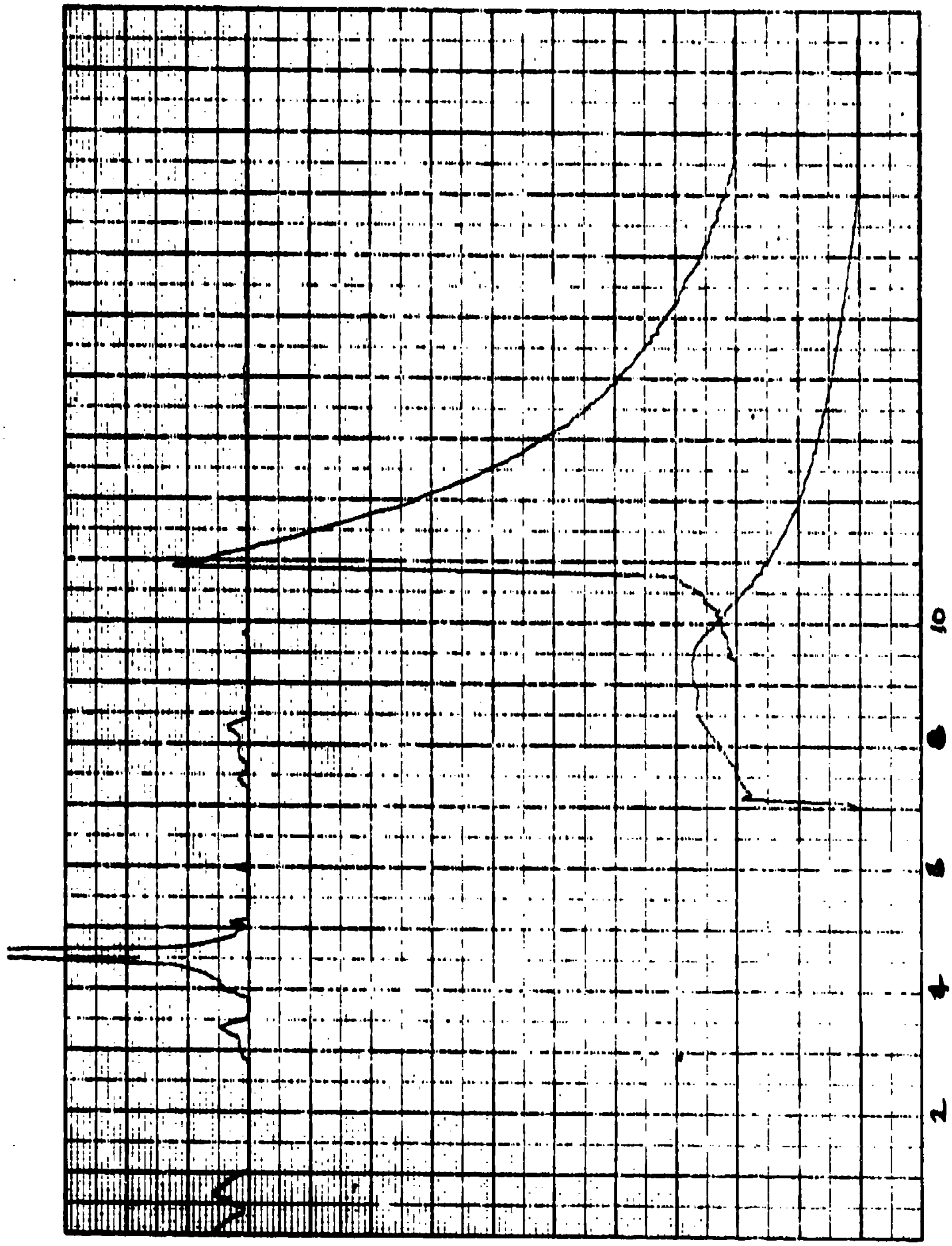
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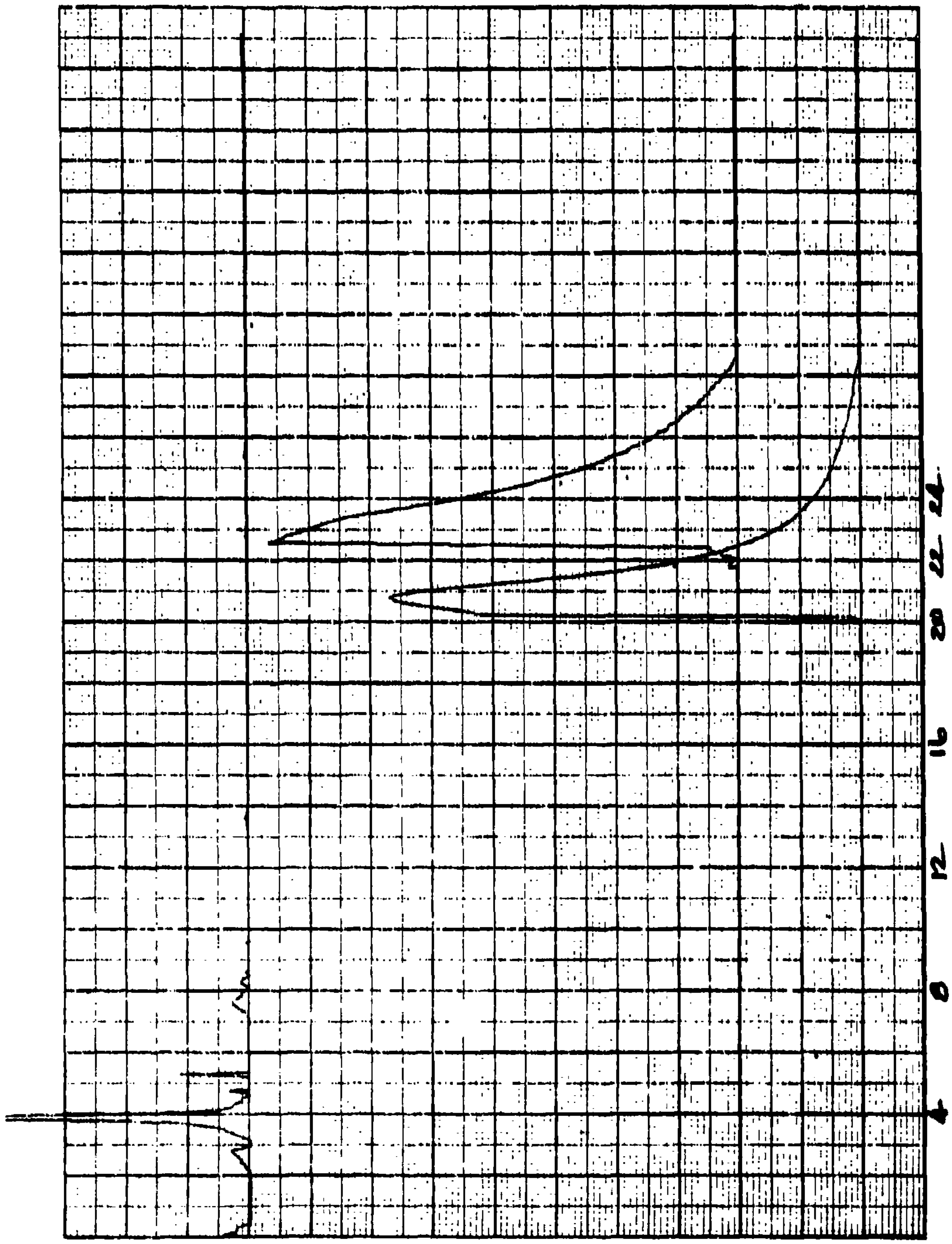
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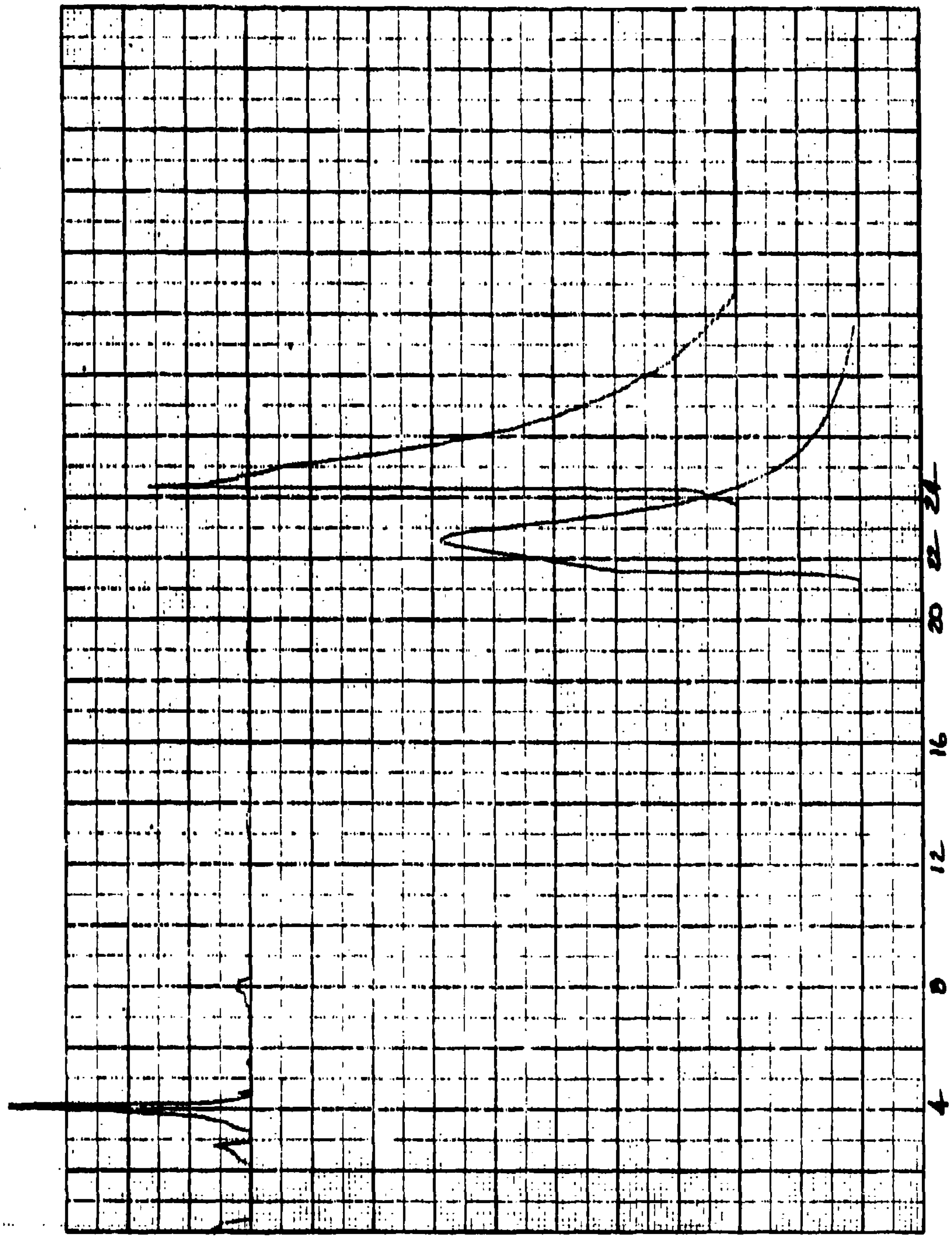
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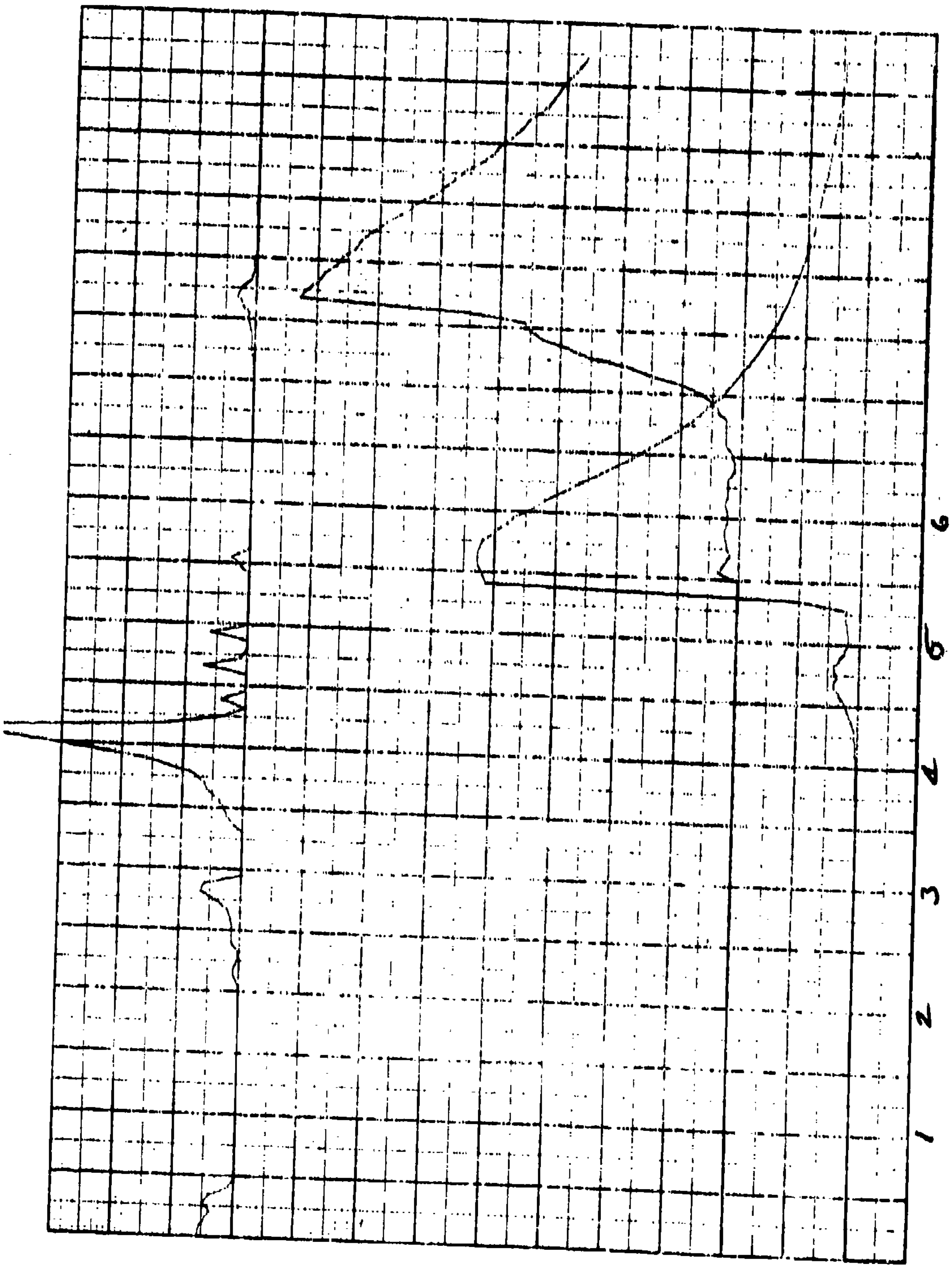
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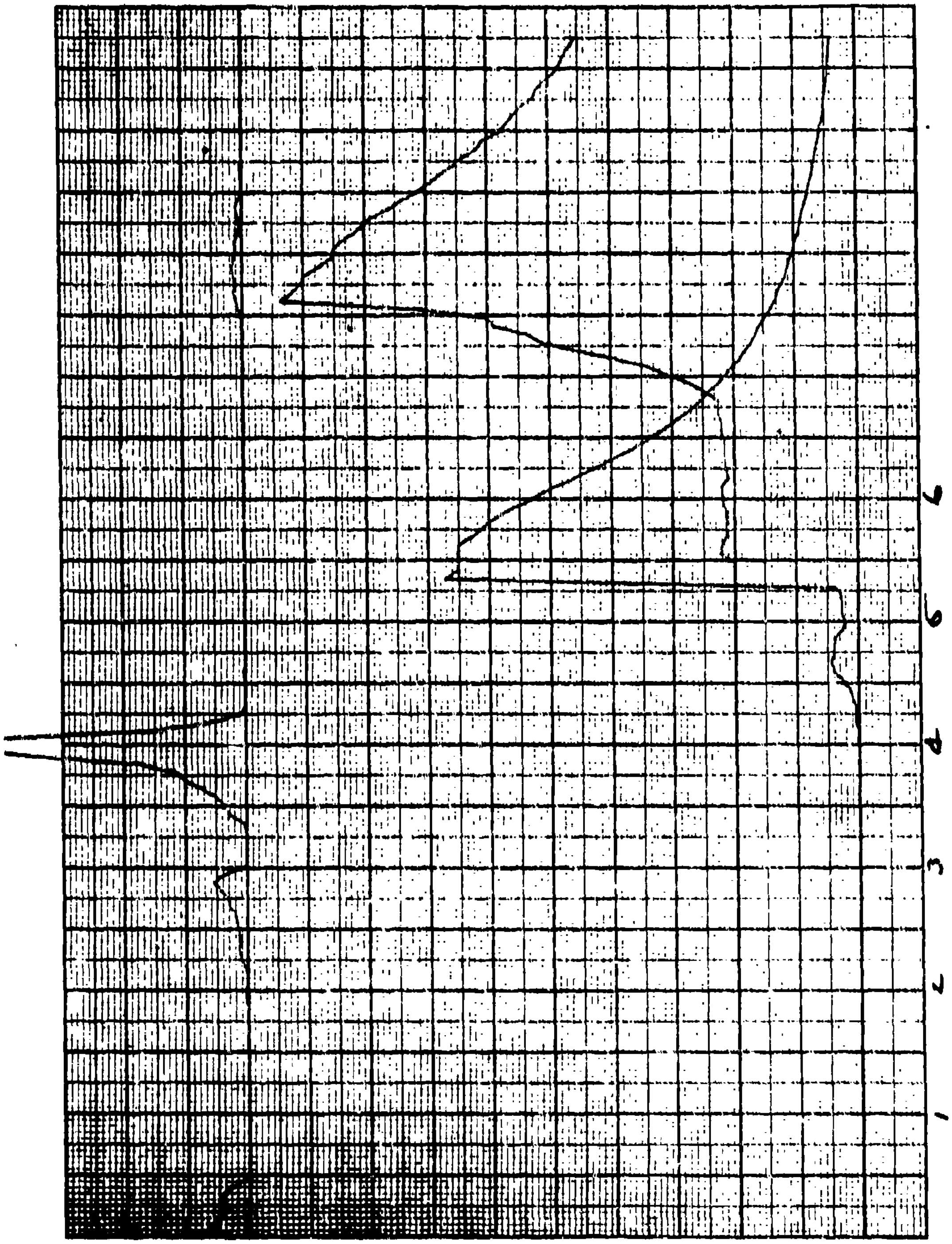
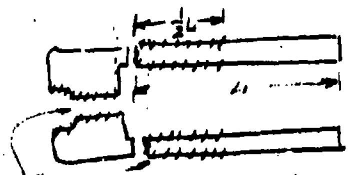




NEOPRENE COATS (2)

25MM PLASTIC CASE
AMMUNITION DEVELOPMENT

−65°F

S/N: [illegible]
DATE: 2[illegible] AUG 74
ENGR: CARY
AMMO: CATRON

OBJECTIVE: TO COMPARE THE COMPUTER DATA ACQUISITION SYSTEM TO THE TAPE DECK/VISICORDER

Test Fixture: IITRI, UNIVERSAL, RIA.
Cartridge Case: Dwg. No. SK 300460, Rev.____, Mat'l NYLON 12, 30% GLASS
Dwg. No.______, Rev.____, Mat'l______.
Projectile: Dwg. No. 300347, Rev. A, Plastic Band, 3000 Grain.
Primer: Type SRM, Lot No.______, No. 22Z 450M
Flash Tube: 32560, 38 Special, ______.
Projectile Retention: 40 Mil NC, 10 Mil Mylar, ______
Ignitor: BP CLASS (3), Seals: NYLON - SK 300558X
Propellant: Fwd Charge 5072, Lot No.______.
Aft Charge 8492-1, Lot No.______.
Insert______, Lot No.______.

REMARKS: PAINT INSIDE OF AFT GRAIN AND AFT HALF OF FORWARD GRAIN - TWO (2) COATS - NEOPRENE - SEE SKETCH

amb

ROUND NO.	PROPELLANT WT (GRAMS)			TOTAL PROP. WT	IGNITOR WT
	FWD	AFT	INSERT	(GRAMS)	(GRAMS)
133	86.2	45.6			0.75
134	86.6	45.9			
135	86.4	45.8			
136	86.3	45.9			
137	86.1	45.8			
138	86.2	45.9			
139	86.2	45.9			
140	86.3	45.7			
141	86.[illegible]	45.8			
142	86.7	45.8			
143	87.0	45.9			
144	76.8	45.7			
145	87.0	45.8			
146	86.9	45.7			
147	86.8	45.8			

FORM NO. SG-555-81

25MM PLASTIC CASE
AMMUNITION DEVELOPMENT

S/N [illegible] 18
DATE 23 AUG 76
ENGR. CANN
AMMO. CATRON

OBJECTIVE: DATA ACQUISITION SYSTEM COMPARISONS

Test Fixture: IITRI, UNIVERSAL, RIA.
Cartridge Case: Dwg. No. SK 300460, Rev.____, Mat'l NYLON 11, 30% GLASS
Dwg. No.______, Rev.____, Mat'l______.
Projectile: Dwg. No. 300347, Rev. A, Plastic Band, 3000 Grain.
Primer: Type SRM, Lot No.______, No. CCI 450M
Flash Tube: 325 38 Special, ______.
Projectile Retention: 40 Mil NC, 10 Mil Mylar, ______
Ignitor: BP Class 3, Seals: ______
Propellant: Fwd Charge 5022, Lot No.______,
Aft Charge 2422.1, Lot No.______,
Insert______, Lot No.______.

REMARKS: PAINT INSIDE OF 1ST SEAM AND AFT HALF OF FORWARD SEAM - TWO (2) COATS - NEOPRENE - SKETCH PAGE 1

ROUND NO.	PROPELLANT WT (GRAMS) FWD	AFT	INSERT	TOTAL PROP WT (GRAMS)	IGNITOR WT (GRAMS)
148	87.1	45.9			0.75
149	87.3	45.8			
150	86.8	45.9			
151	86.8	45.7			
152	87.0	45.8			
153	86.8	45.8			
154	87.0	45.7			
155	86.6	45.8			
156	87.6	45.9			
157	87.6	45.9			
158	87.3	45.8			
159	87.2	45.9			
160	87.4	45.6			
161	87.4	45.5			
162	87.0	45.7			

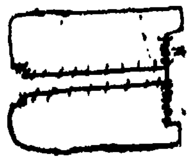
45.6

FORM NO. SG-555-81

−65°F

Rd. Number	TA	PI	PS	DY	[illegible]
133	—	50.0 k	6.4 k	1912	—
134	13.79	37.5 k	9.2 k	2252	—
135	24.15	45.5 k	10.7 k	2424	2405
136	10.94	48.0 k	8.45 k	2204	2202
137	No Data	Recorded			
138	14.4	45.5 k	9.9 k	2238	2207
139	No Data	Recorded			
140	28.26	79.5 k	11.6 K	2817	2901
141	8.30	120.0 K	12.5 K	3855	3748
142	23.60	64.0 K	12.5 K	2619	2664
143					
144					
145		Computer	Malfunction		
146					
147	10.60	49.0 k	9.50 k	2317	2292
148	No Data	Recorded			
149	80.15	148.5 K	13.45 K	4033	3997
150	31.90	157.5 K	12.20 k	3940	3878
151	No Data	Recorded	—		
152	> 10 Sec.	146.5 K	13.10 K	3973	3936
153	12.28	58.5 k	6.8 K	2021	2009
154	30.86	97.0 k	14.0 K	3218	3191
155	31.60	106.0 k	12.95 k	3148	3121
156	14.27	17.0 k	1.75 k	1833	1836

[illegible]	15.99	27.5 k	8.65 k	1946	1915
[illegible]	7.10 sec	149.5 k	11.95 k	3831	3784
[illegible]	27.78	64.0 k	13.25 k	2782	2759
160	25.40	0	5.35 k	992	985
161	40.38	181.0 k	13.4 k	3985	3897
162	25.84	91.0 k	13.9 k	2969	2956



2 Coats Neoprene

25MM PLASTIC CASE
AMMUNITION DEVELOPMENT

S/N: 19
DATE: ____
ENGR: ____
AMMO: ____

OBJECTIVE: Effect of Different Primers Plain Pistol Versus Small Rifle and Small Rifle Magnum

Test Fixture: IITRI, UNIVERSAL, RIA.
Cartridge Case: Dwg. No. SK 300460, Rev.____, Mat'l Nylon 12, 38% Glass
Dwg. No. ____, Rev.____, Mat'l ____.
Projectile: Dwg. No. 300347, Rev. A, Plastic Band, 3000 Grain.
Primer: Type ____, Lot No.____, No.____.
Flash Tube: 3256W, 38 Special, ____.
Projectile Retention: 40 Mil NC, 10 Mil Mylar, Banded To Fwd. Case
Ignitor: ____, Seals: ____
Propellant: Fwd Charge 5477, Lot No.____.
Aft Charge 8446-9, Lot No.____.
Insert ____, Lot No.____.

REMARKS: ____

ROUND NO.	PROPELLANT WT (GRAMS) FWD	AFT	INSERT	TOTAL PROP. WT (GRAMS)	IGNITOR WT (GRAMS)
163	88.32	46.0		0	0 .75 Class 3
164	88.48	46.2		0	0
165	88.04	46.2		0	0
166	88.04	46.1		0	
167	88.04	46.0		0	
168	88.36	46.2			
169	87.43	46.1			
170	88.40	46.2			
171	88.63	46.2			
172	87.79	46.1			
173	87.38	46.1			
174	88.92	46.0			

FORM NO. SG-555-81

25MM PLASTIC CASE
AMMUNITION DEVELOPMENT

S/N: 19
DATE:
ENGR:
AMMO:

OBJECTIVE:

Test Fixture: IITRI, UNIVERSAL, RIA.
Cartridge Case: Dwg. No. SK 300460, Rev.____, Mat'l______.
Dwg. No. ______, Rev.____, Mat'l______.
Projectile: Dwg. No. 300347, Rev. A, Plastic Band, 3000 Grain.
Primer: Type______, Lot No.______, No.______.
Flash Tube: 3288W, 38 Special, ______.
Projectile Retention: ______Mil NC, ______Mil Mylar, ______Mil ______
Ignitor:______, Seals:______
Propellant: Fwd Charge______, Lot No.______.
Aft Charge______, Lot No.______.
Insert______, Lot No.______.

REMARKS:

ROUND NO.	PROPELLANT WT (GRAMS) FWD	AFT	INSERT	TOTAL PROP. WT (GRAMS)	IGNITOR WT (GRAMS)
175	47.64	45.8			.75 class 3
176	47.83	46.0			
177	47.60	46.0			

FORM NO. SQ-555-81

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RUNNH

OPTION FOR P2   1=RR    2=P2MAX?2
DISTANCE TO FIRST LIGHT SCREEN?37.583
DISTANCE BETWEEN LIGHT SCREENS?7.833
X-RAD   1=YES  2=NO?2

P1 MAX      P2 MAX     P3 MAX     VELOCITY    TIME     B.E.  P.E.
----------------------------------------------------------------
ROUND NO--?163

?ARG AT LINE 520

READY

GOTO 230
ROUND NO--?164

?ARG AT LINE 520

READY

GOTO 230
ROUND NO--?164
  -.4          14.1        7.11        2891      6.97     .013 -21.288
  0            18.69       4.92
LS1 TO LS2 2912
P3 TO LS2 2895
ROUND NO--?165
  50       -.2             6.94        2758      6.9      .012  .172
  82.88     0              6.4
LS1 TO LS2 2770
P3 TO LS2 2760
ROUND NO--?166
  39.7     -.2             5.3         2331      6.9      9.00000E-03
 .155
  77.17     0              10.64
LS1 TO LS2 2320
P3 TO LS2 2329
ROUND NO--?167
  59.7     -.2             7.33        2987      6.83     .014  .169
  81.24     0              5.78
LS1 TO LS2 2988
P3 TO LS2 2987
ROUND NO--?168
  49       -.1             5.95        2587      6.63     .011  .155
  76.81     0              11.01
LS1 TO LS2 2582
P3 TO LS2 2586
```

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ROUND NO--?169
   54.1      -.2            6.01         2717     6.7       .012  .155
   75.04      0             9.96
LS1 TO LS2 2785
PG TO LS2 2715
ROUND NO--?170
   43.5      -.1            6.39         2492     7.11      .01   .162
   76.7       0             10.08
LS1 TO LS2 2525
PG TO LS2 2497
ROUND NO--?171
   58.2      -.1            7.44         2801     6.76      .012  .153
   76.6       0             11.38
LS1 TO LS2 2839
PG TO LS2 2808
ROUND NO--?172
   51.9      -.2            6.85         2758     7.11      .012  .166
   77.58      0             10.05
LS1 TO LS2 2705
PG TO LS2 2749
ROUND NO--?173
   24        -.1            3.97         1438     6.15      3.00000E-03
 .098
   22.69      0             5.63
LS1 TO LS2 1723
PG TO LS2 1481
ROUND NO--?174
   44.9      -.1            5.64         2403     7.73      9.00000E-03
 .146
   74.43      0             14.86
LS1 TO LS2 2418
PG TO LS2 2406
ROUND NO--?175
   40.6       0             6.92         2503     8.21      .01   .175
   77.19      0             15.36
LS1 TO LS2 2525
PG TO LS2 2507
ROUND NO--?176
   43.7      -.1            6.18         2341     7.86      9.00000E-03
 .142
   75.54      0             18.7
LS1 TO LS2 2368
PG TO LS2 2345
ROUND NO--?177
   24.1       0             4.52         1458     6.21      3.00000E-03
 .1
   26.1       0             9.57
LS1 TO LS2 1723
PG TO LS2 1498
ROUND NO--?9999

STOP AT LINE 2000

READY
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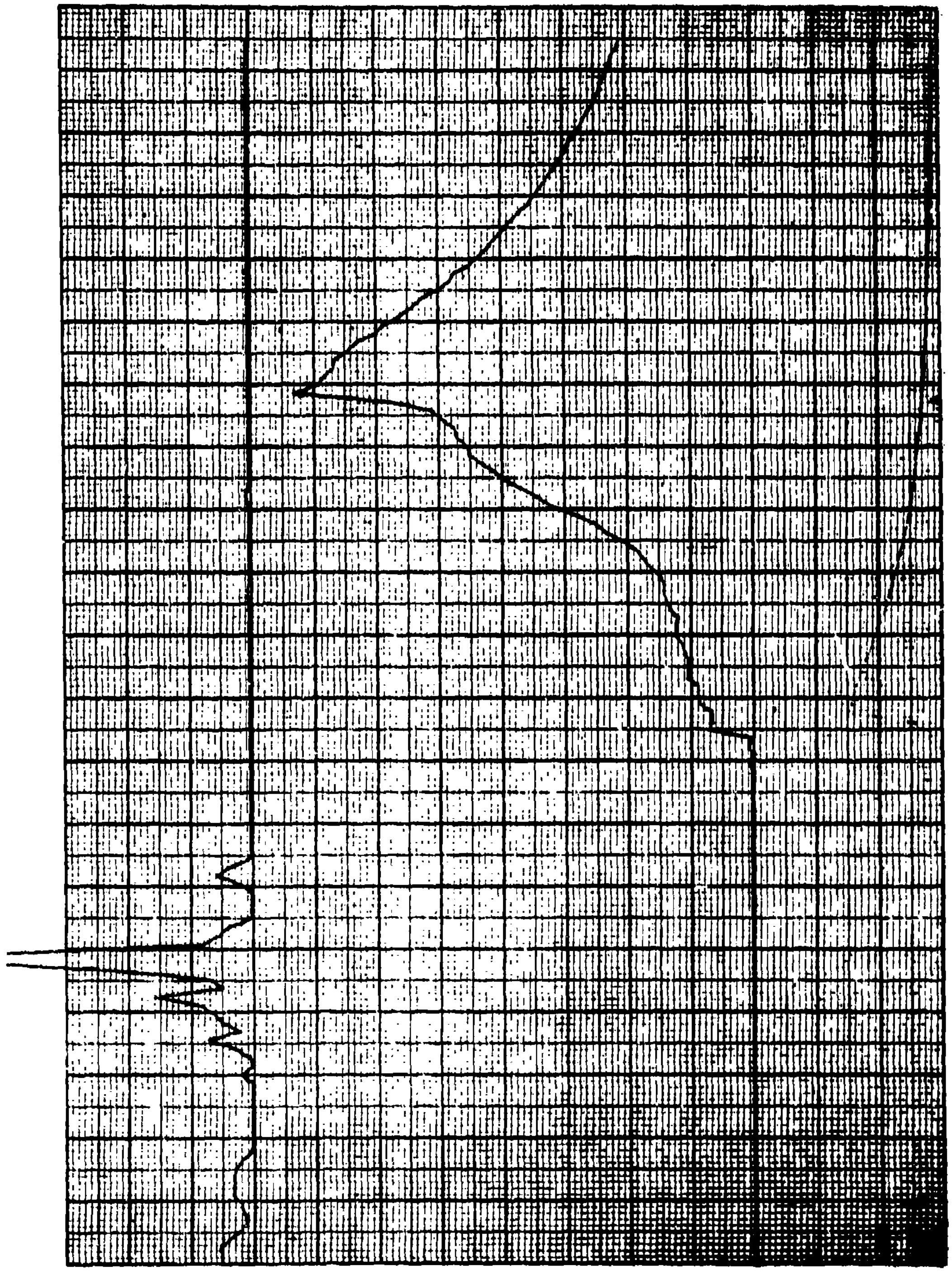

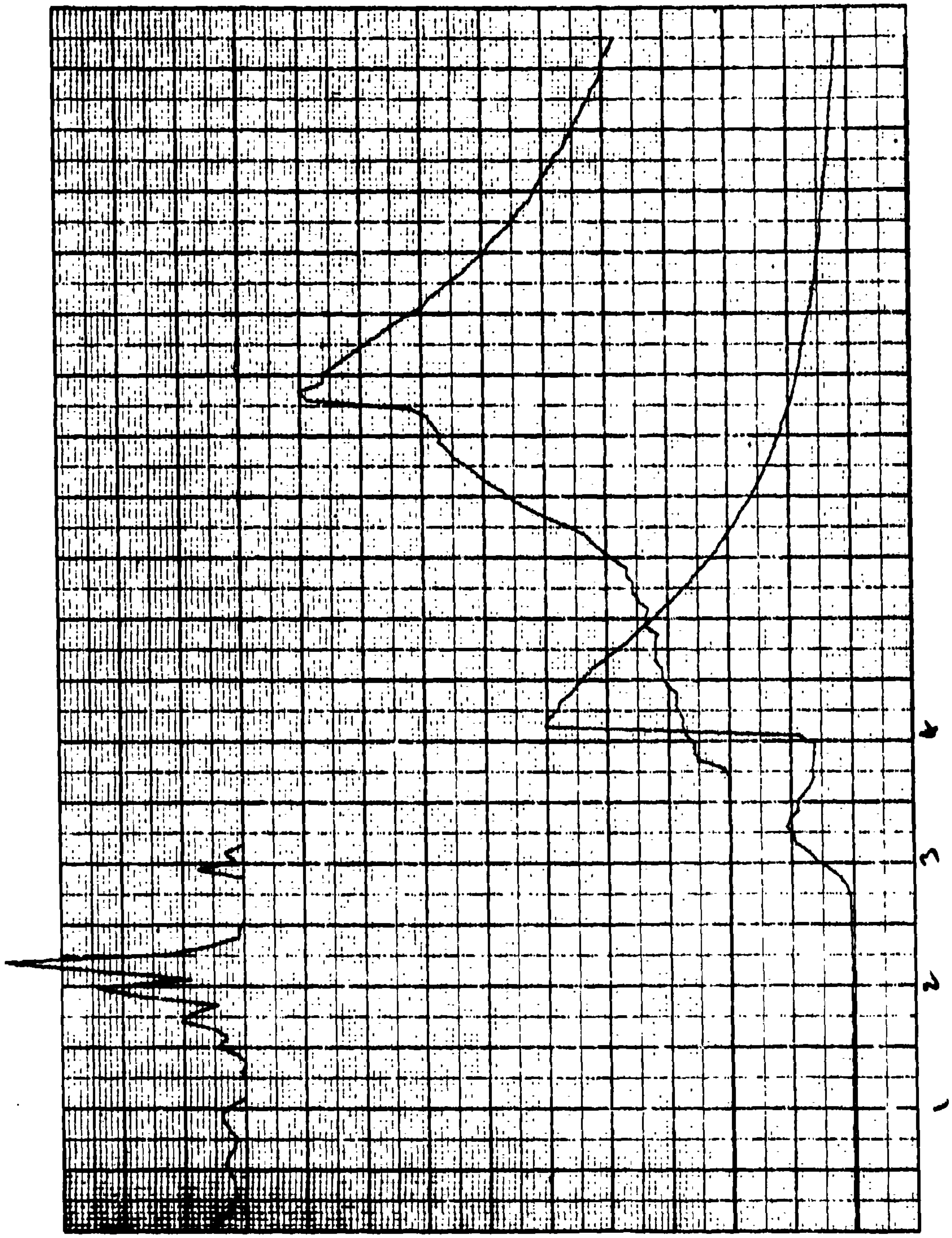
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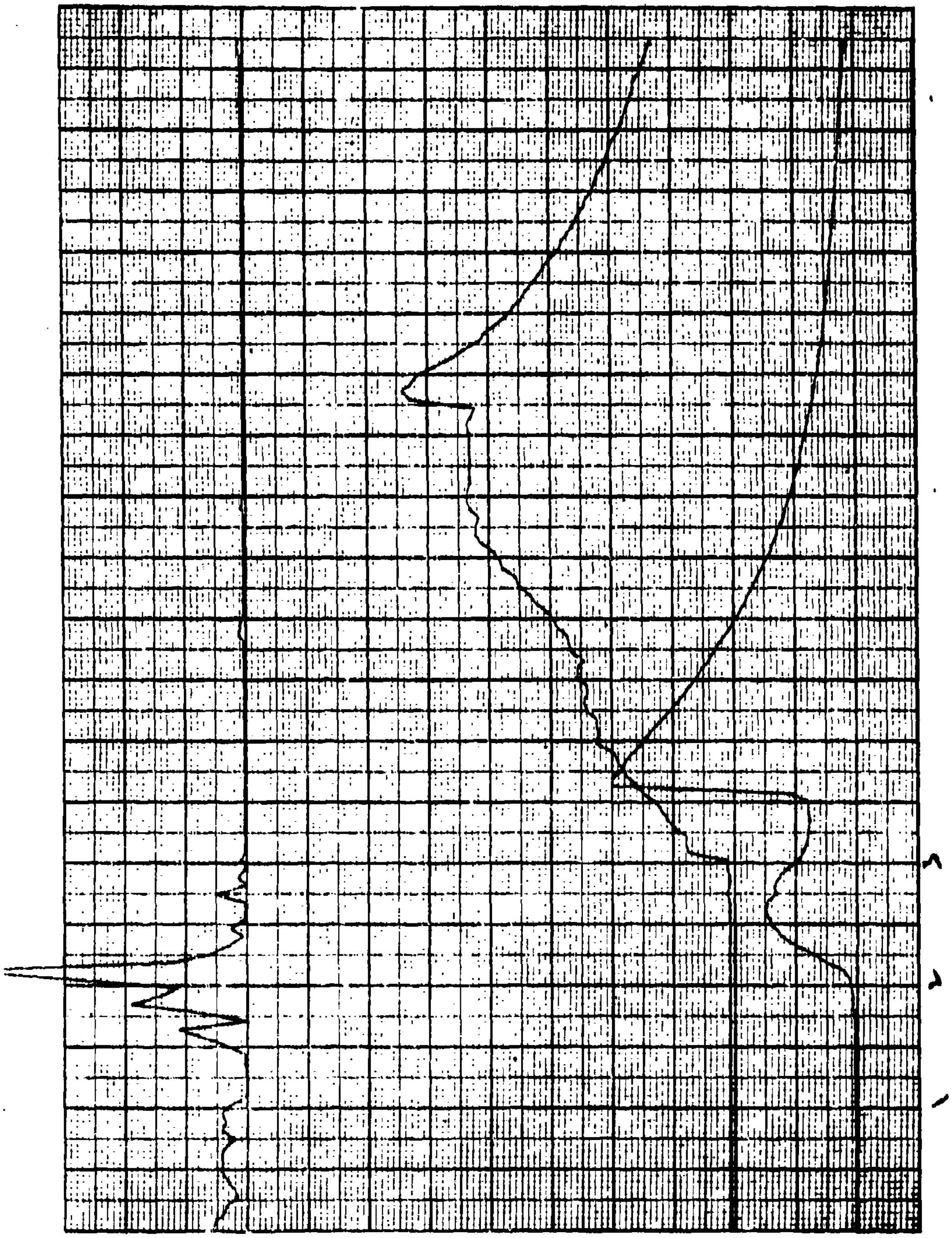

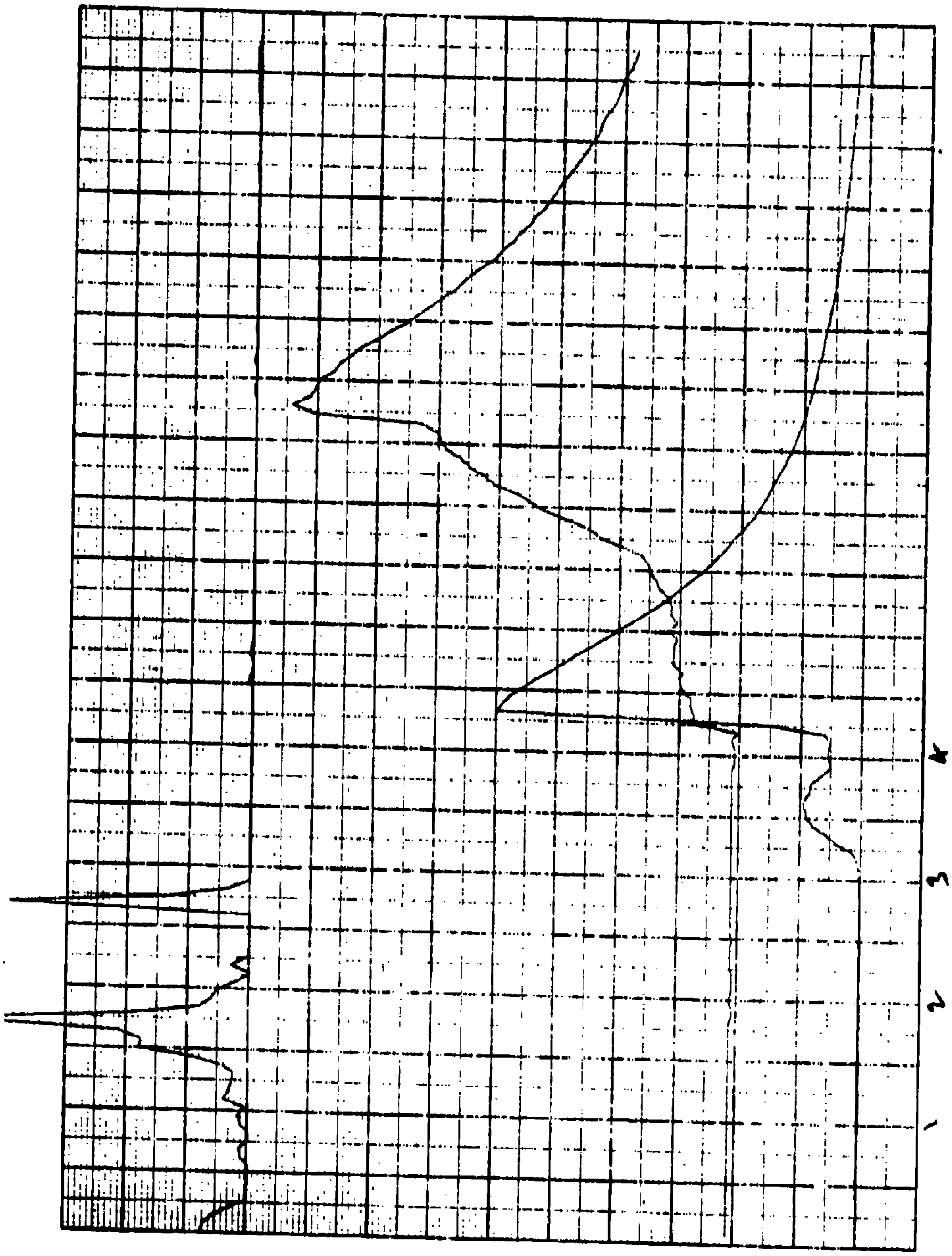

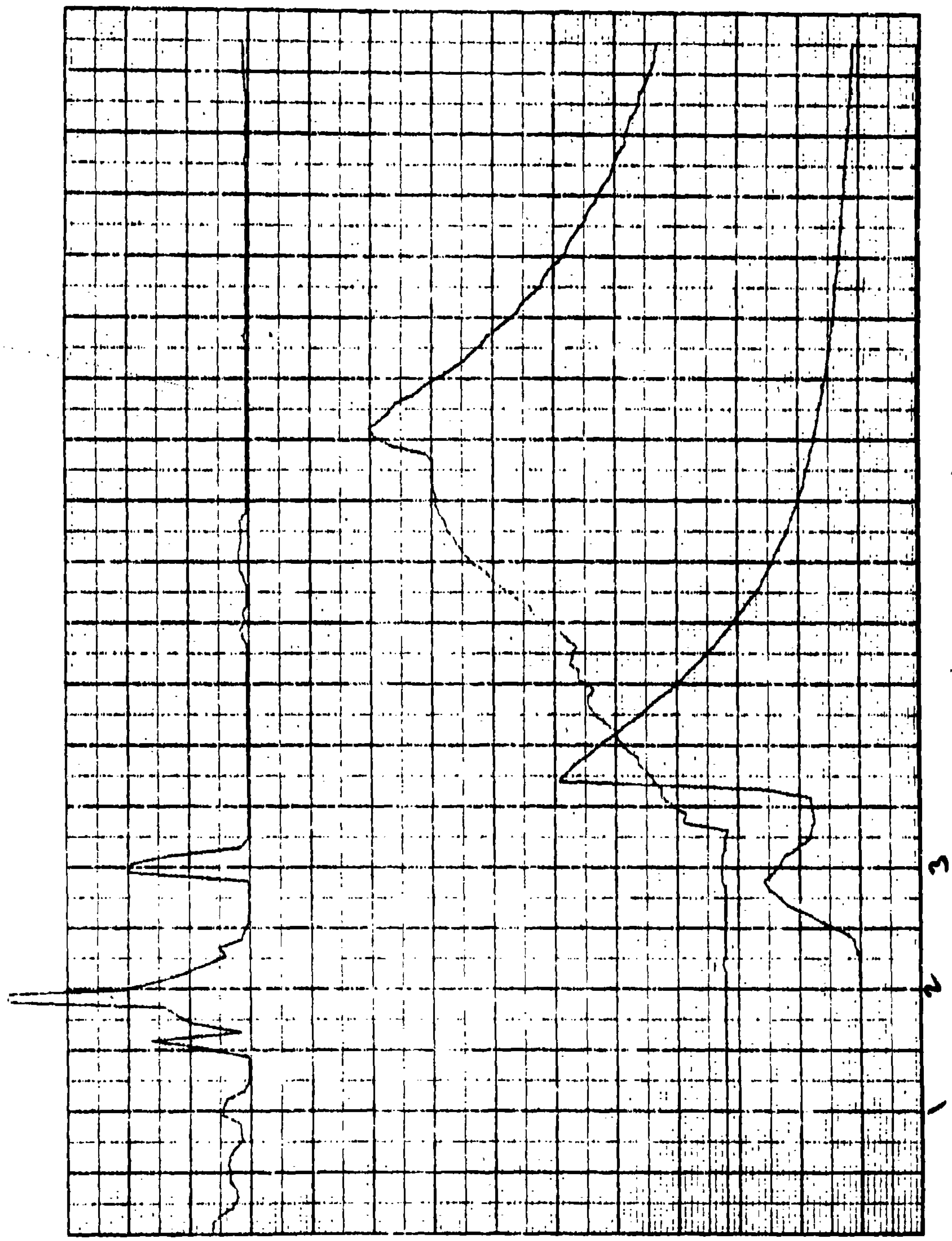
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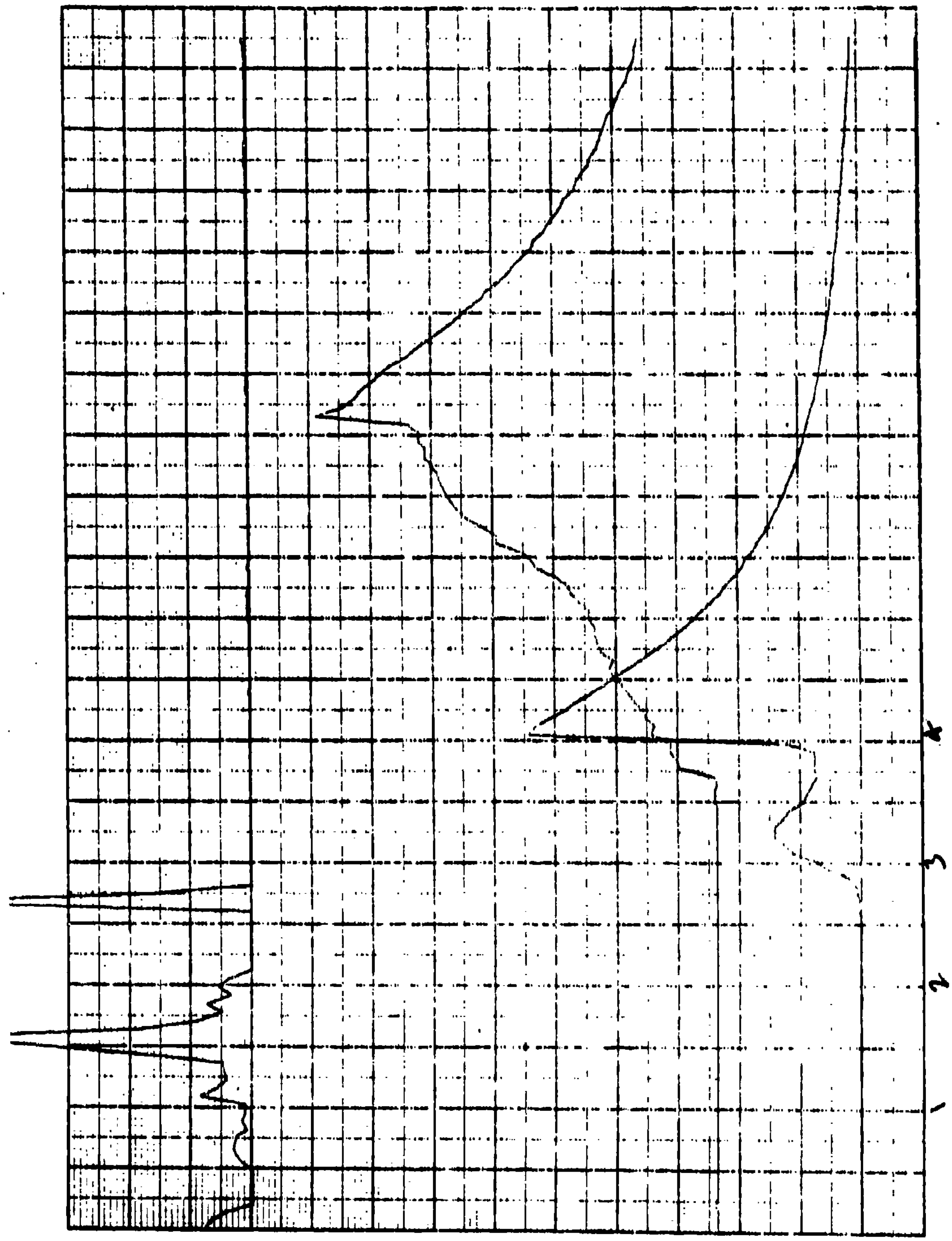
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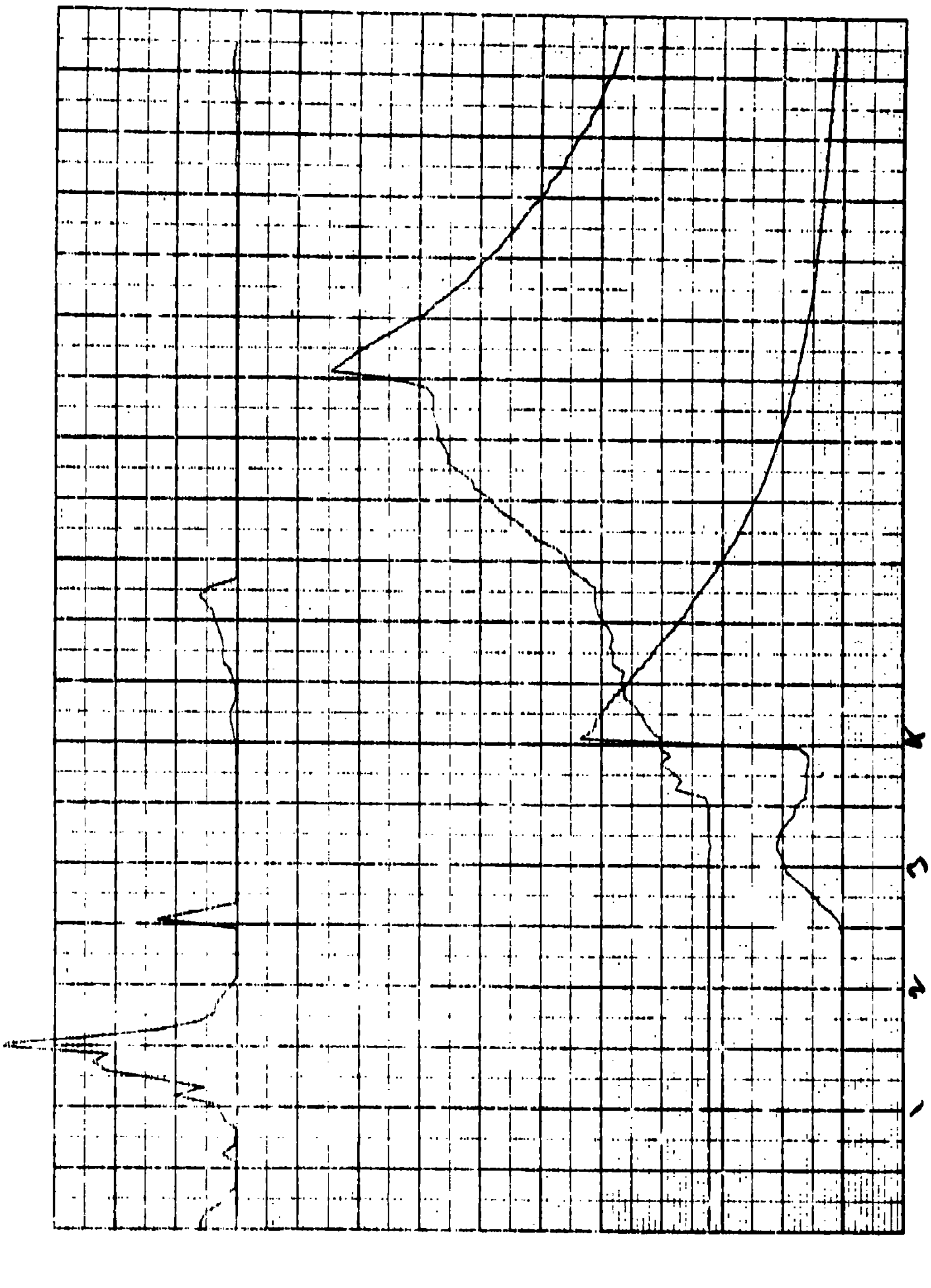

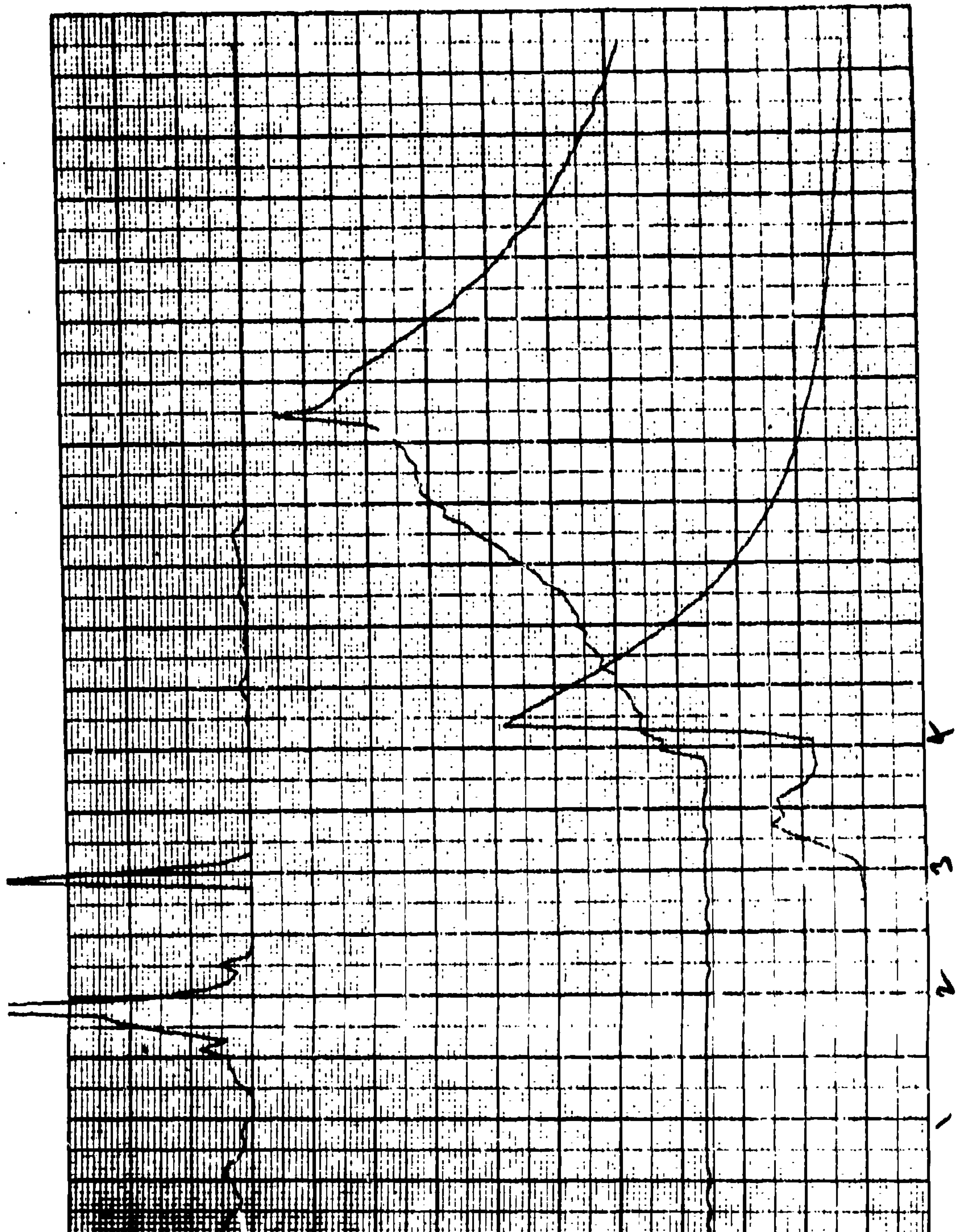
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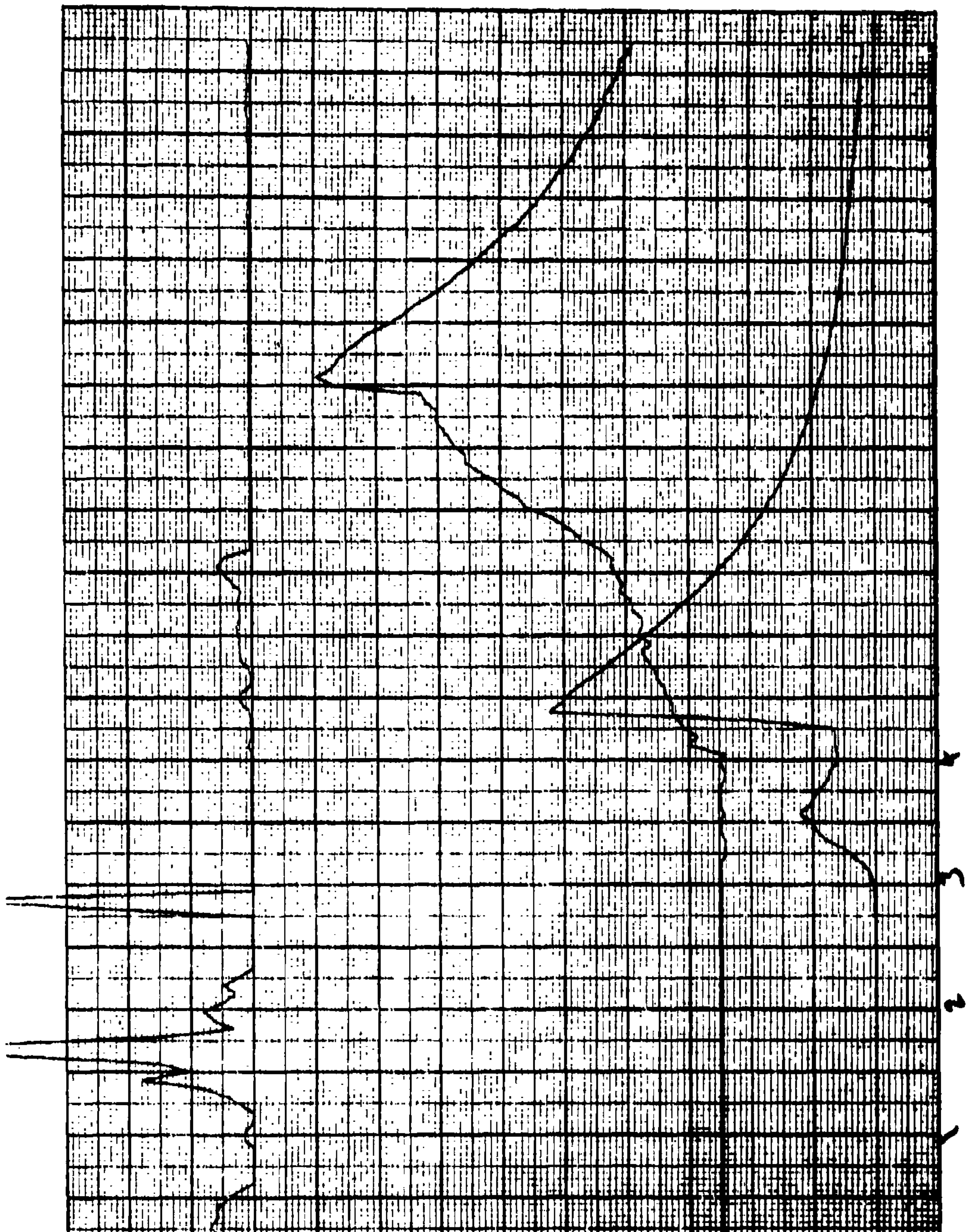

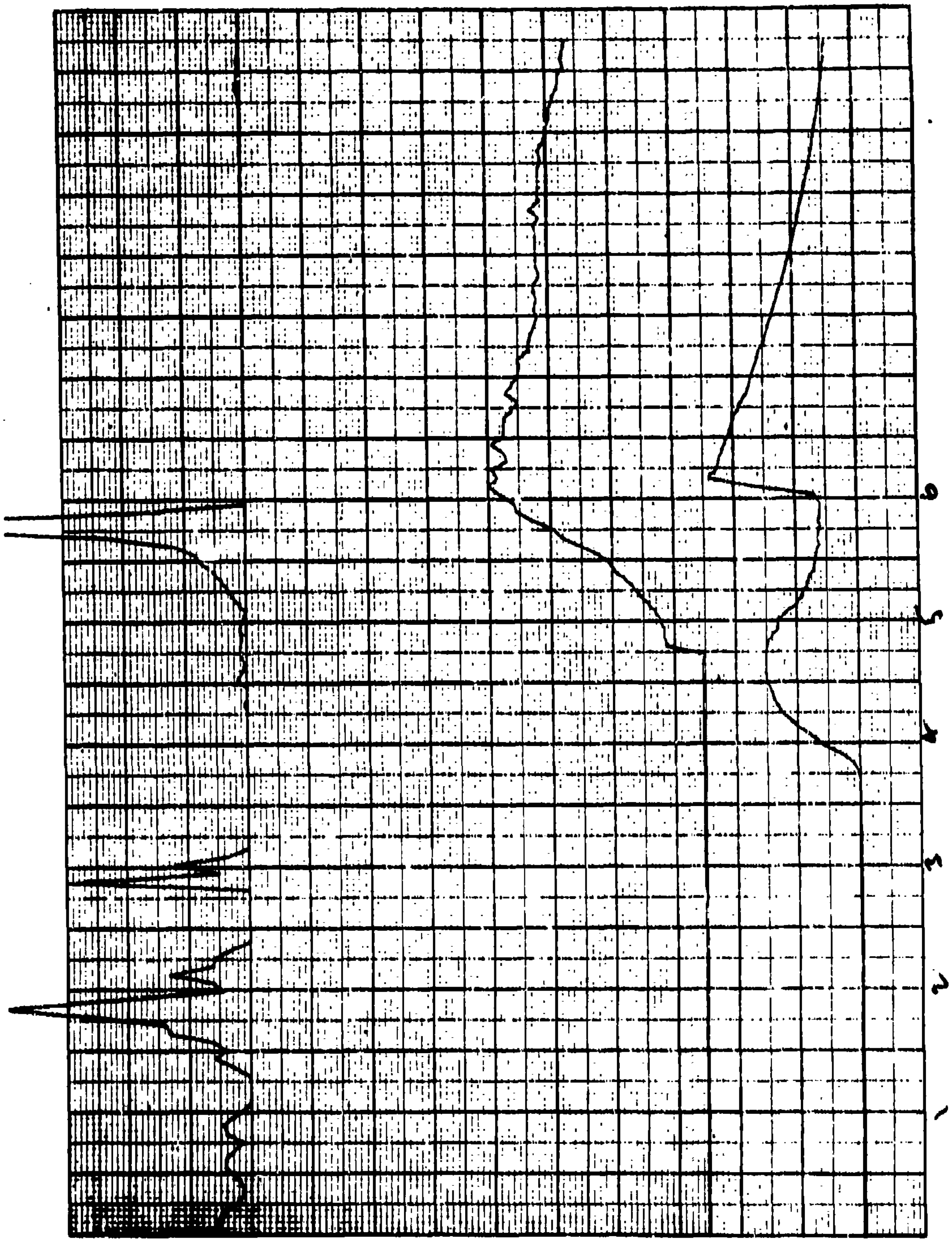
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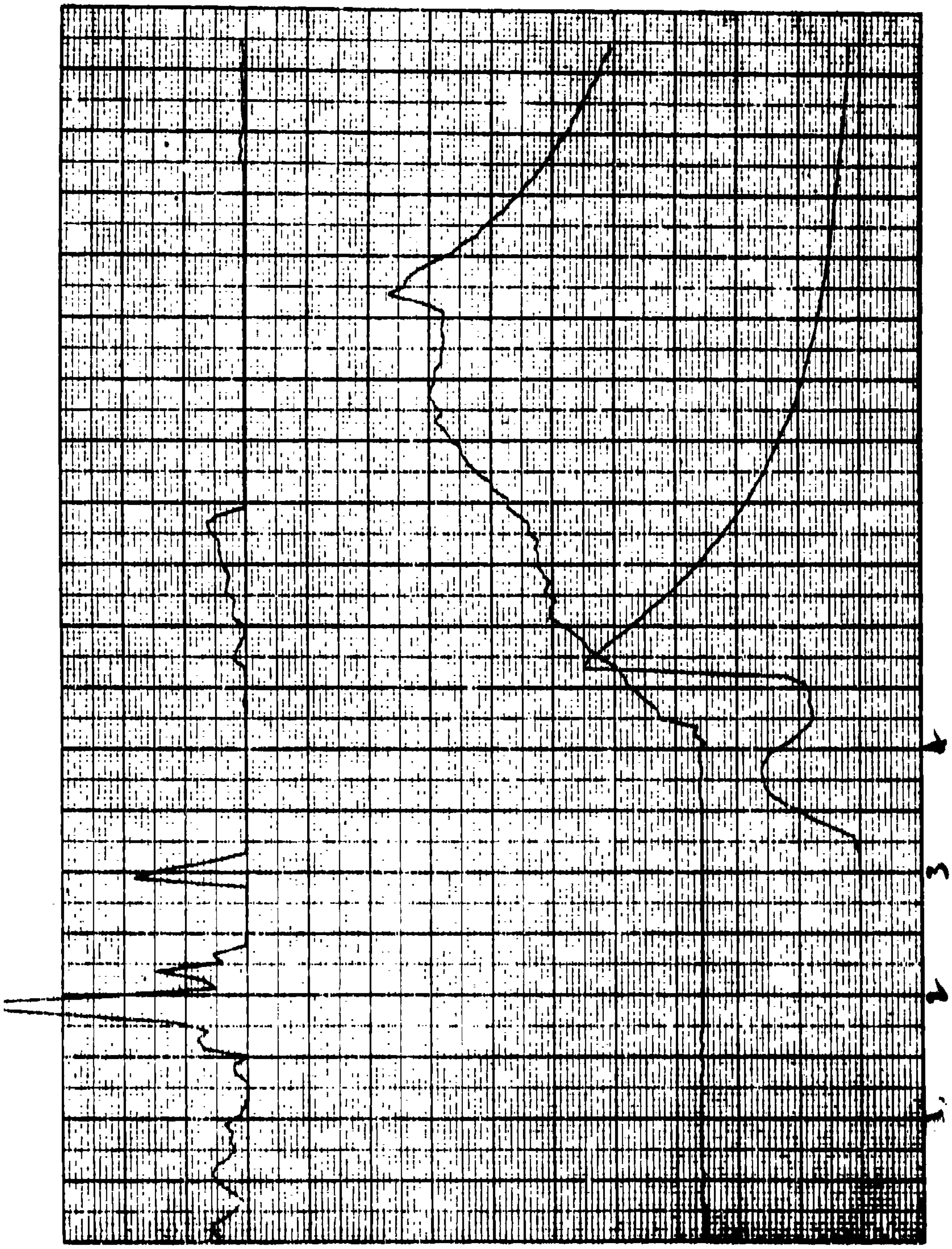

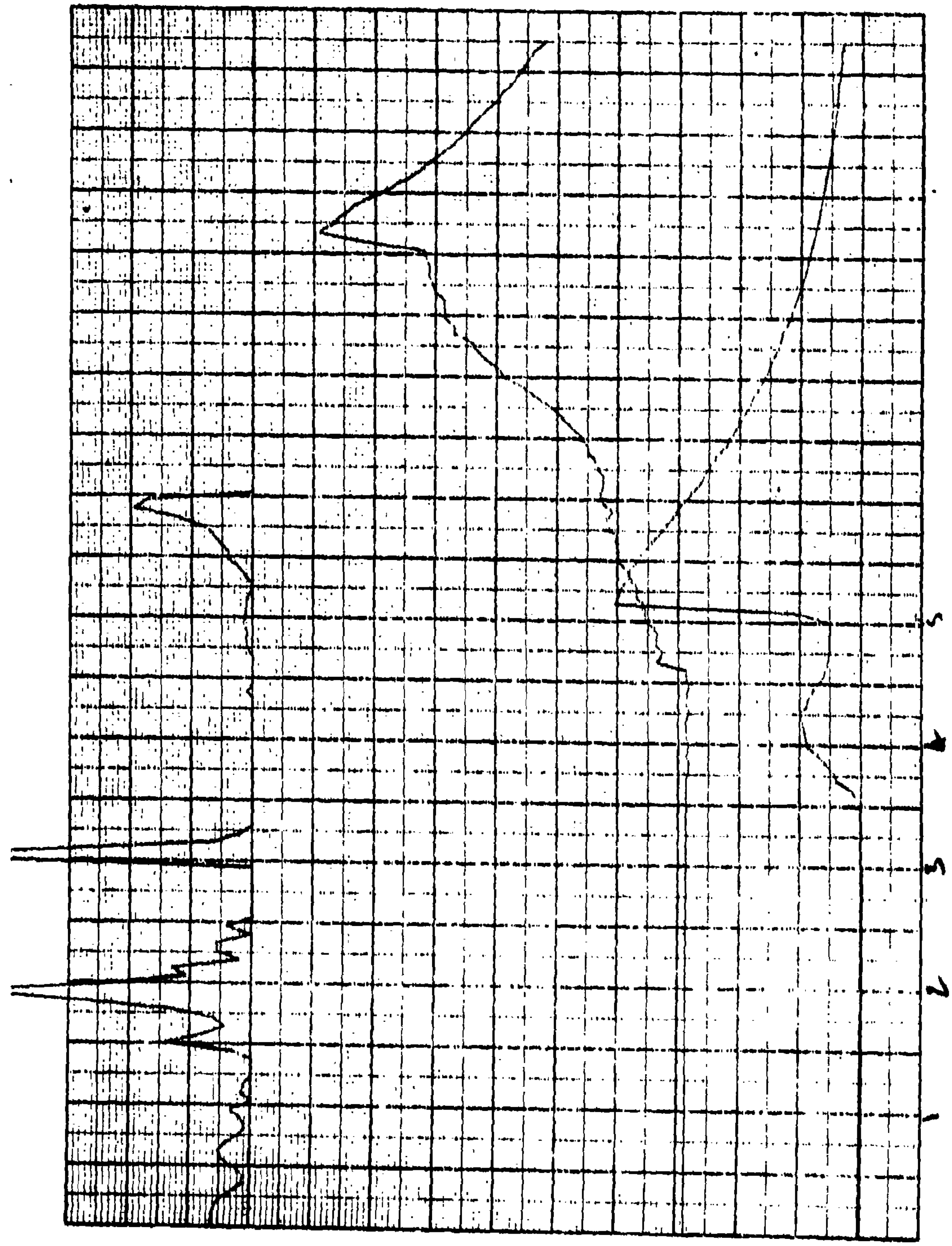
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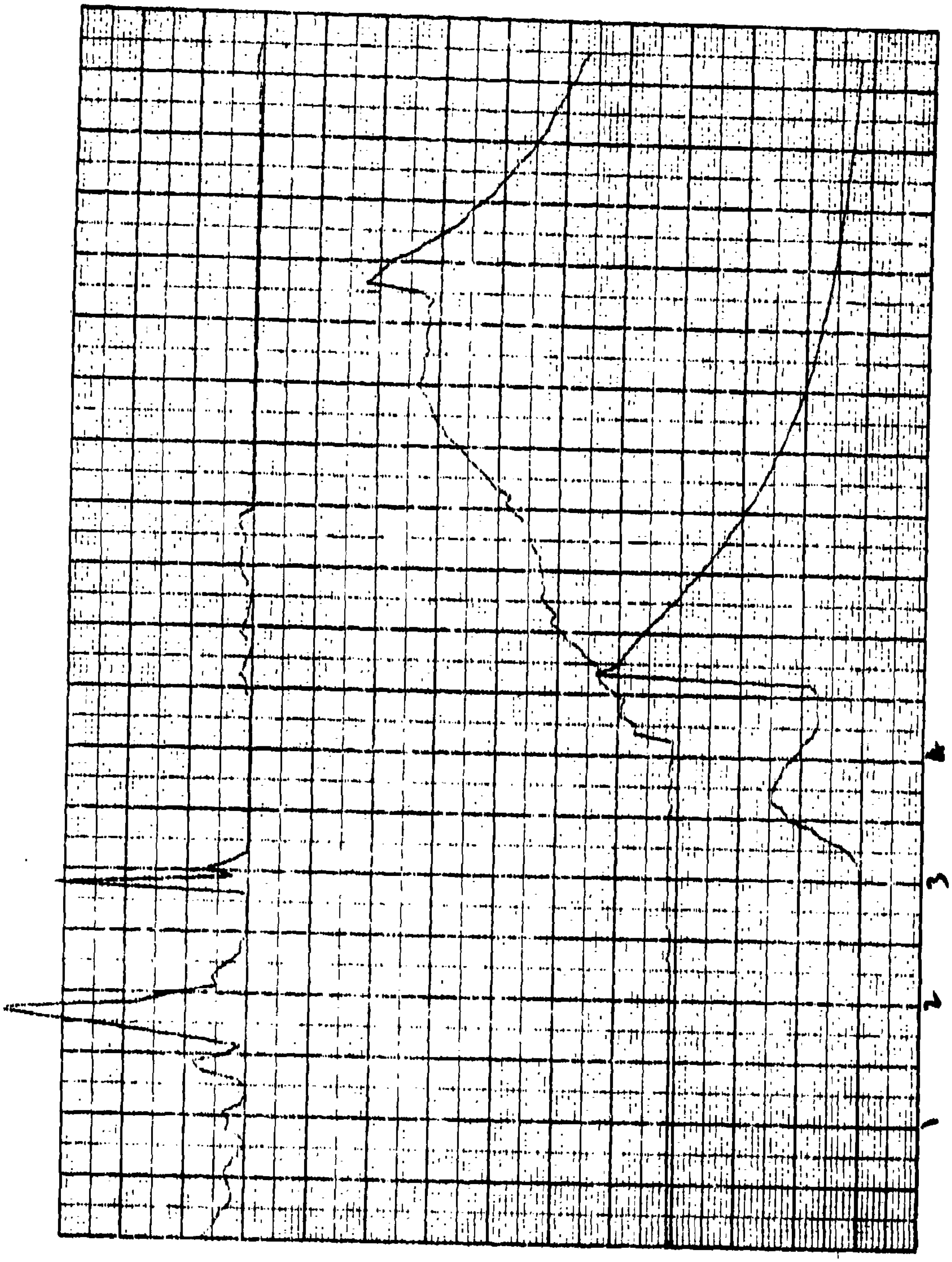
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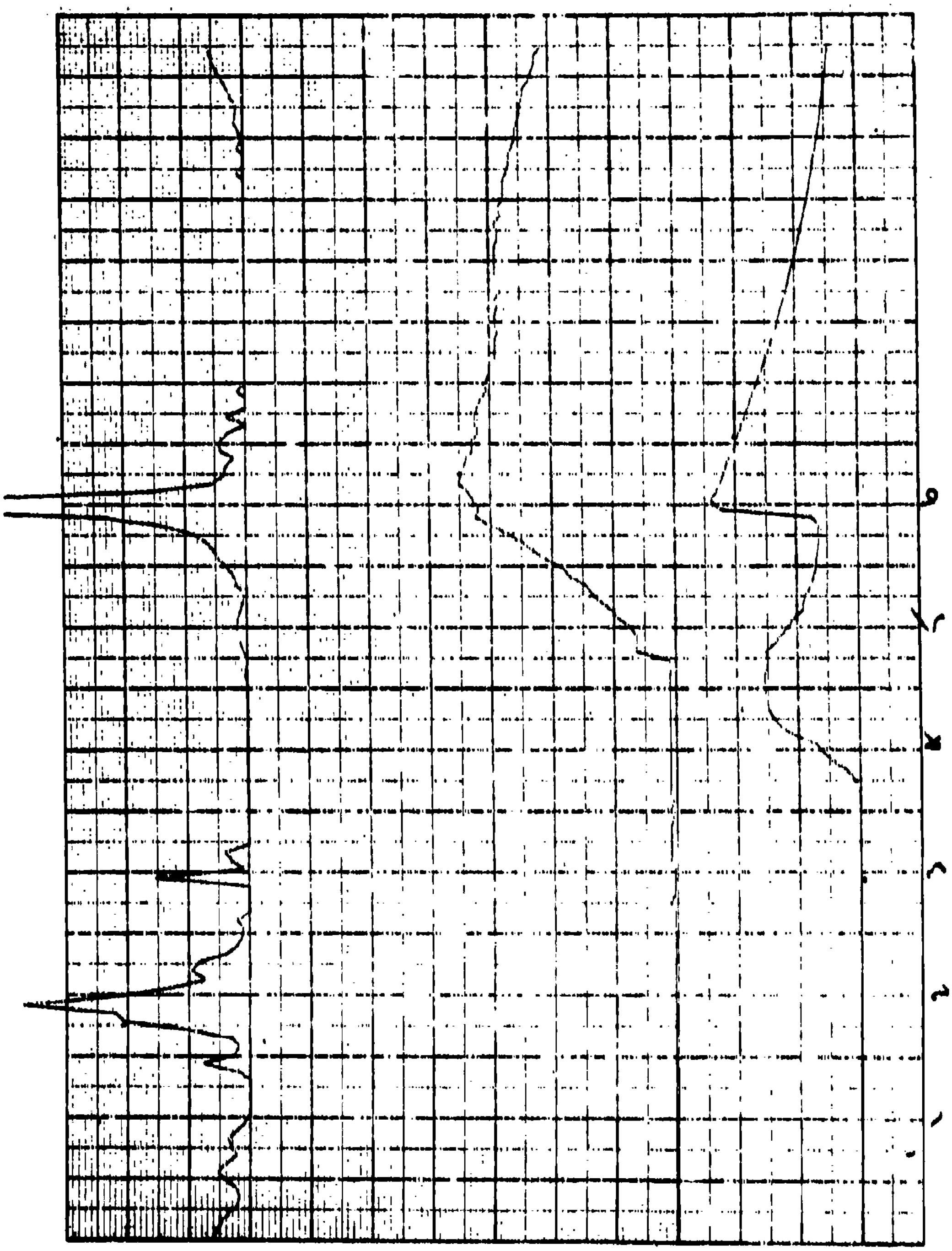

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